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Maynard et al.

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(45) **Date of Patent: Jun. 30, 2015**

(54) **LIFTING DEVICE EFFICIENT LOAD DELIVERY, LOAD MONITORING, COLLISION AVOIDANCE, AND LOAD HAZARD AVOIDANCE**

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(73) Assignee: **Trimble Navigation Limited**, Sunnyvale, CA (US)

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(21) Appl. No.: **14/088,195**

(22) Filed: **Nov. 22, 2013**

(65) **Prior Publication Data**

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(51) **Int. Cl.**

B66C 15/04	(2006.01)
G01C 21/00	(2006.01)
B66C 13/46	(2006.01)

(52) **U.S. Cl.**

CPC ***B66C 15/045*** (2013.01); ***G01C 21/00*** (2013.01); ***B66C 13/46*** (2013.01)

(58) **Field of Classification Search**

CPC B66C 1/34; B66C 15/045; B66C 13/46; B66C 14/04; G01C 21/00

USPC 701/50, 301, 408, 468; 294/82.15, 294/82.11, 86.41; 254/393, 401; 702/150, 702/152, 153; 340/685; 29/428

See application file for complete search history.

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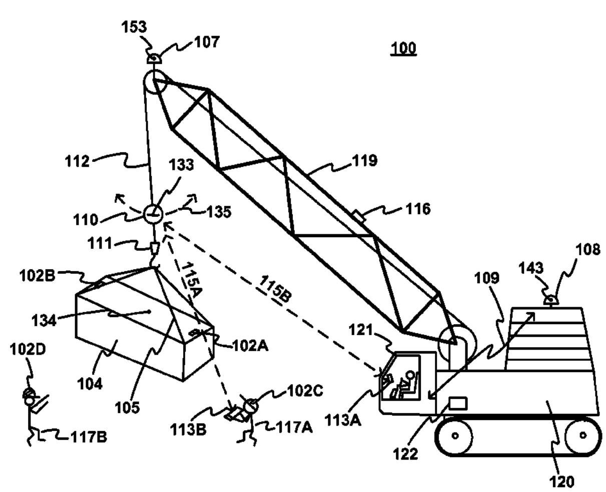
Primary Examiner — Marthe Marc-Coleman

(57) **ABSTRACT**

A hook block sensor assembly is disclosed. In one embodiment, the hook block sensor comprises a housing configured to removably couple about a lifting hook of a lifting device, a first global navigation satellite system (GNSS) receiver coupled with the housing and configured for determining a hook block sensor assembly position in three dimensions, a load monitor coupled with the housing and configured for monitoring a load coupled with the lifting hook, including monitoring a load position and a load orientation of the load and a wireless transceiver coupled with the housing and configured for wirelessly providing information including the load position, the load orientation, and the hook block sensor assembly position, to a display unit located apart from the hook block sensor assembly.

17 Claims, 18 Drawing Sheets



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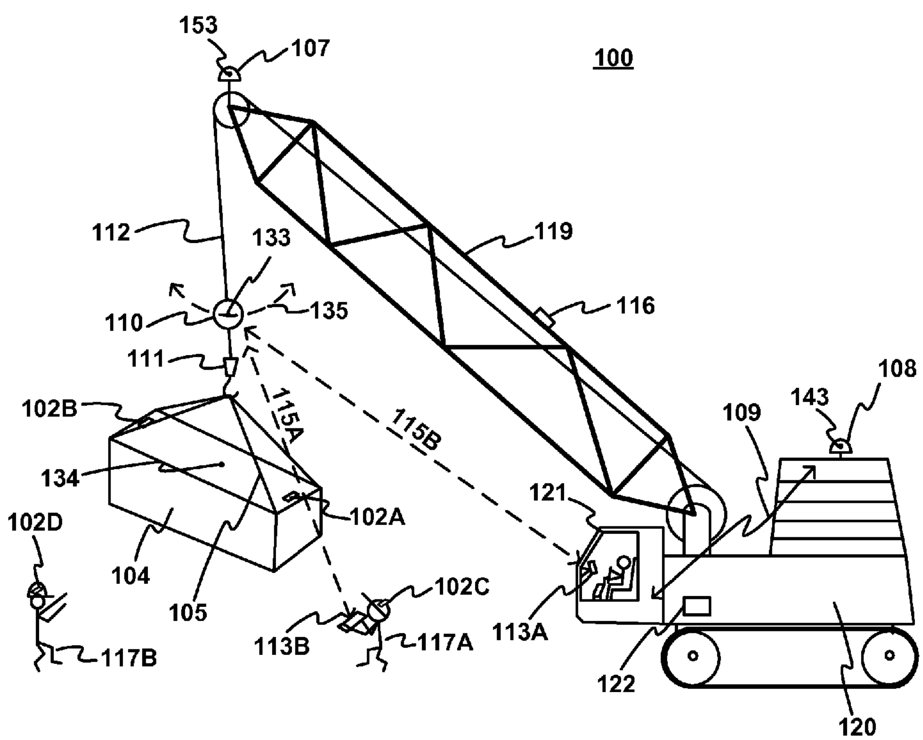


100
153
107
112
133
119
110
135
116
111
115A
115B
108
143
109
102B
134
121
102A
102D
104
105
102C
113B
117A
113A
122
117B
120

FIG. 1A

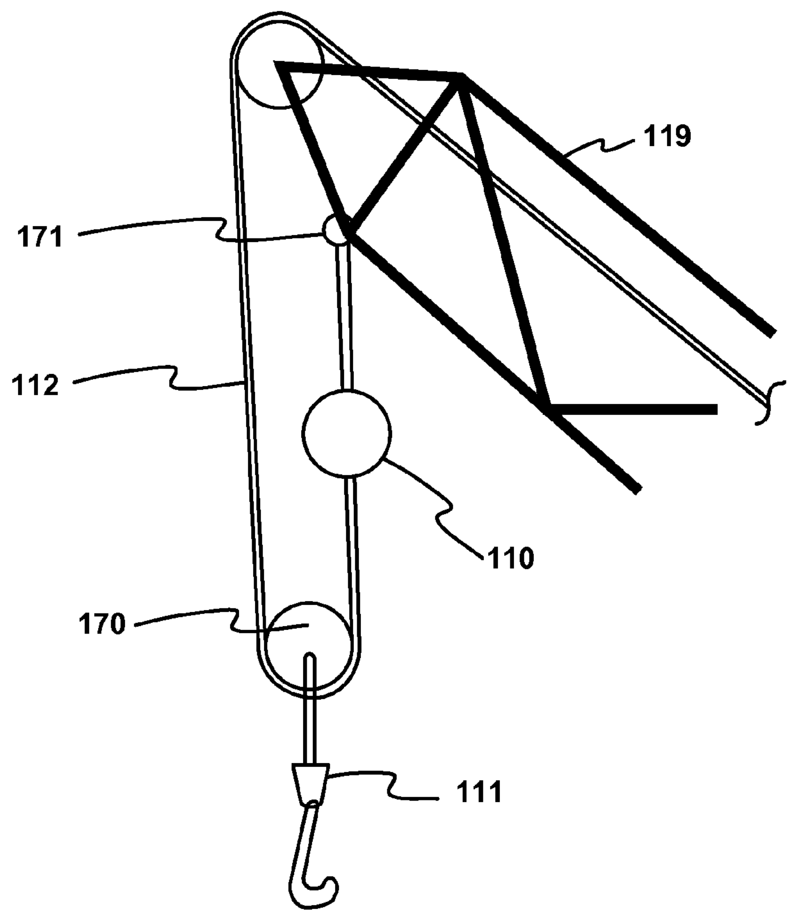
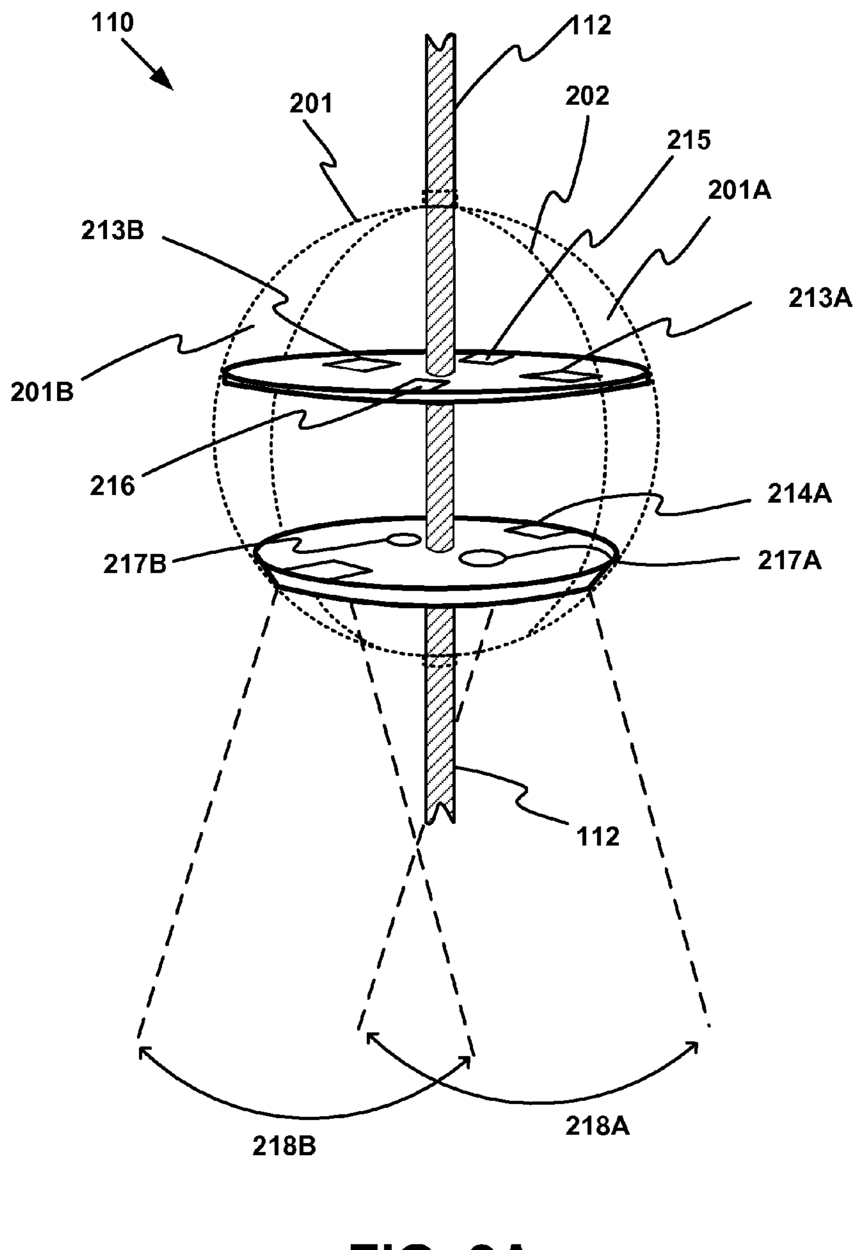


FIG. 1B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213A
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218B
218A

FIG. 2A

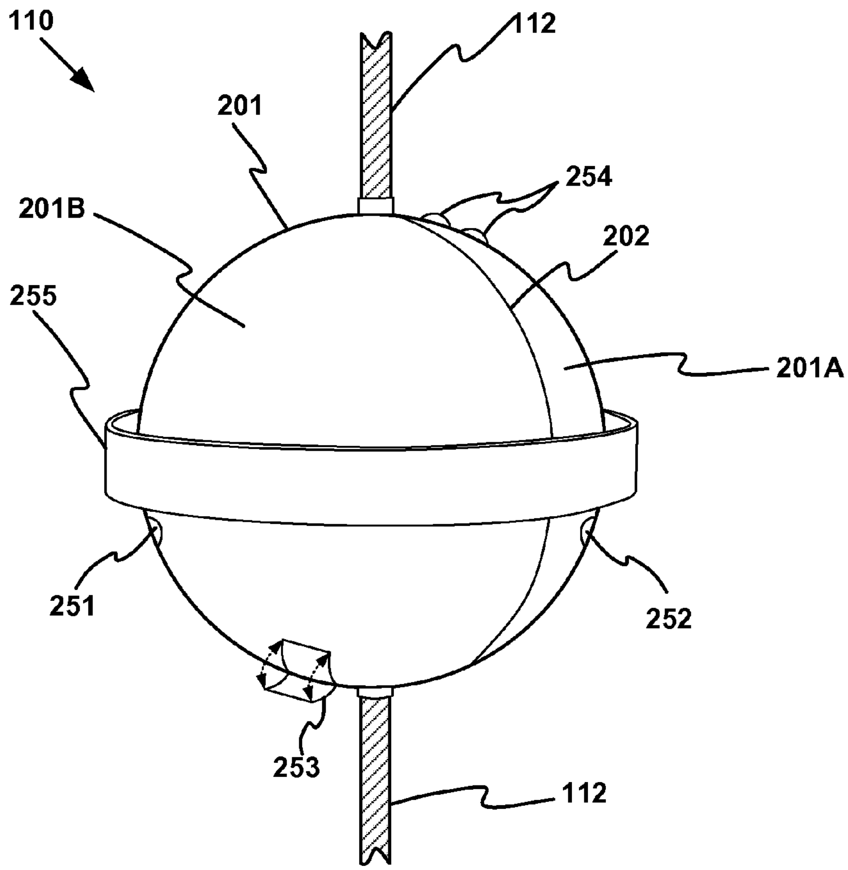


FIG. 2B

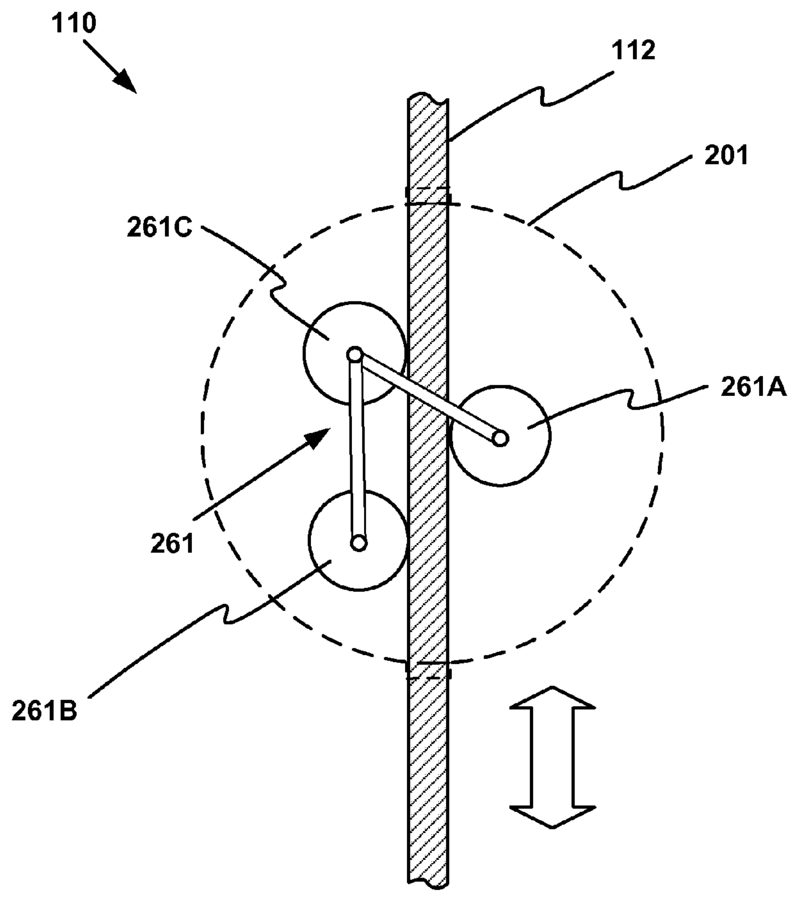


FIG. 2C

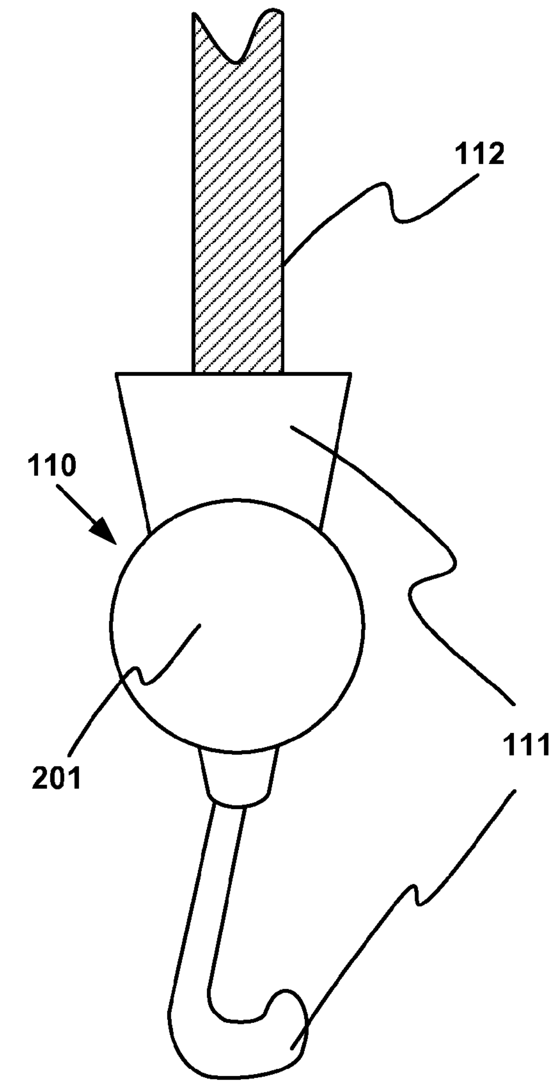


FIG. 2D

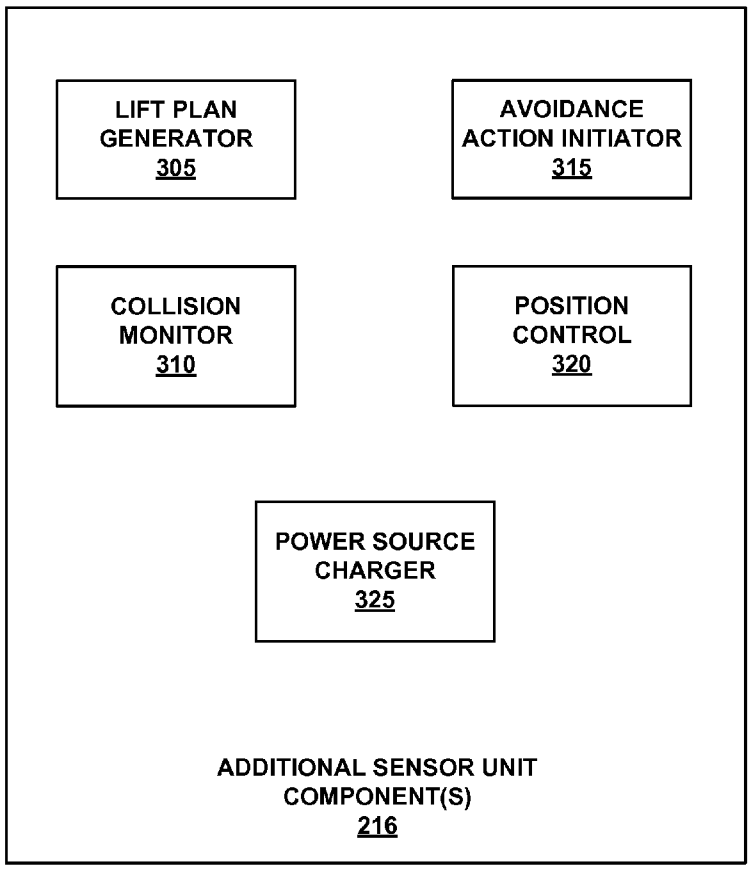

LIFT PLAN
GENERATOR
305
AVOIDANCE
ACTION INITIATOR
315
COLLISION
MONITOR
310
POSITION
CONTROL
320
POWER SOURCE
CHARGER
325
ADDITIONAL SENSOR UNIT
COMPONENT(S)
216

FIG. 3

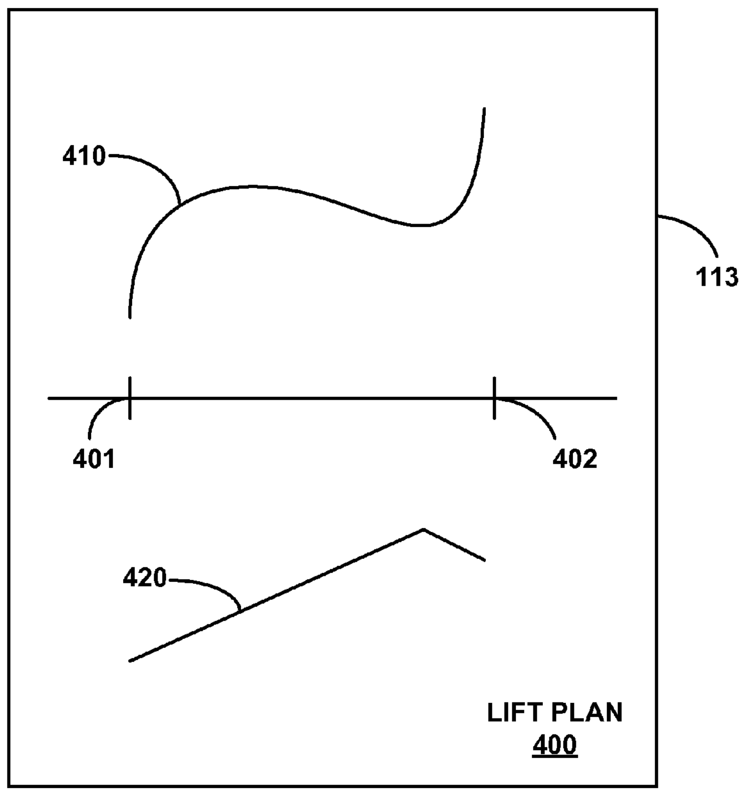
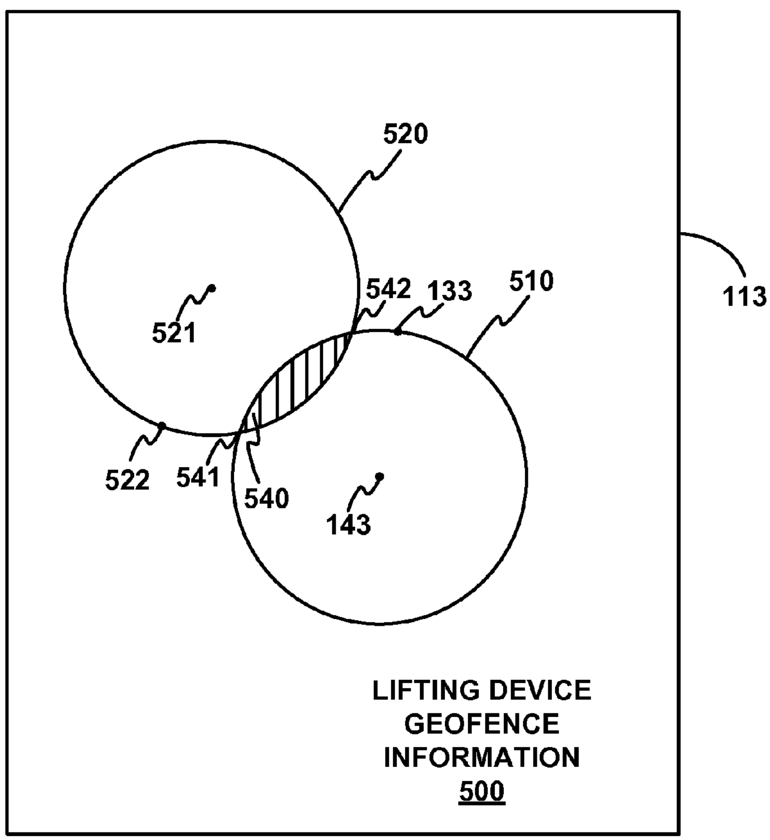


FIG. 4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542
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113
522
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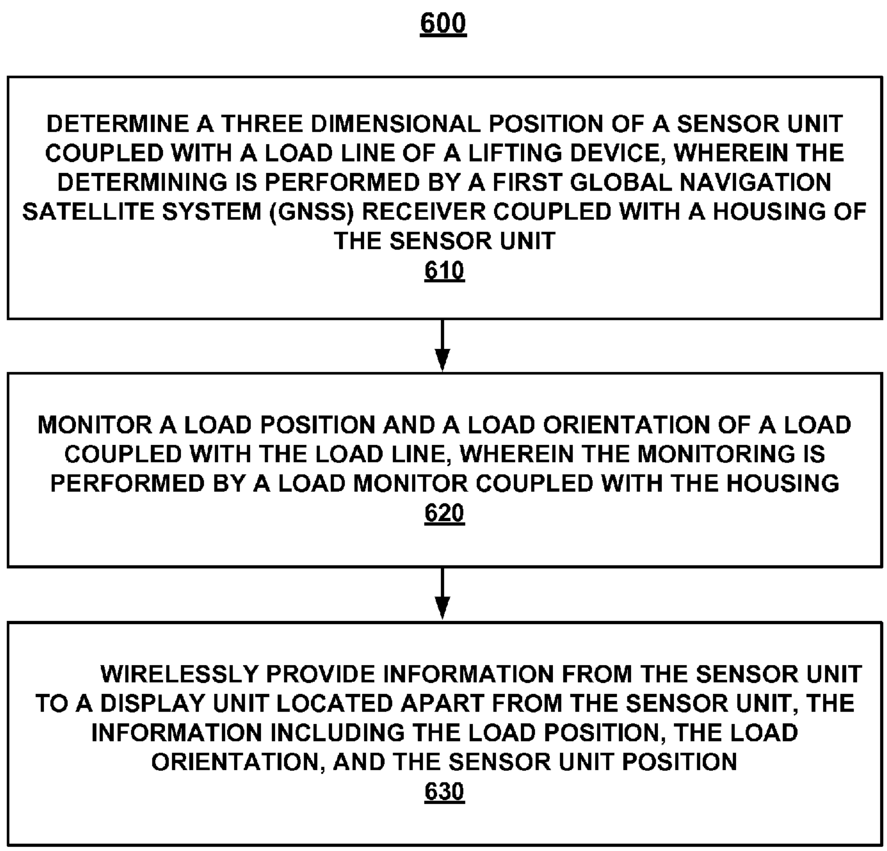
540
143
LIFTING DEVICE
GEOFENCE
INFORMATION
500

FIG. 5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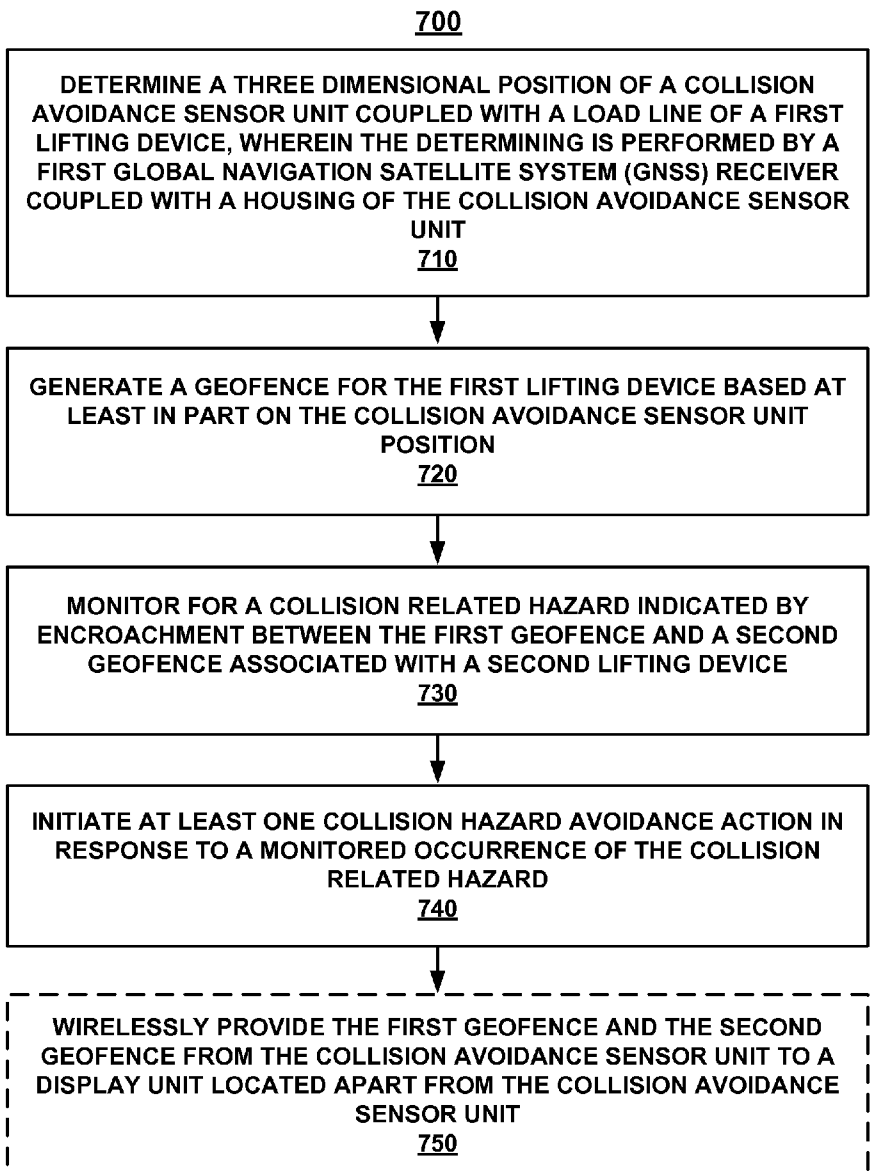
DETERMINE A THREE DIMENSIONAL POSITION OF A SENSOR UNIT COUPLED WITH A LOAD LINE OF A LIFTING DEVICE, WHEREIN THE DETERMINING IS PERFORMED BY A FIRST GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) RECEIVER COUPLED WITH A HOUSING OF THE SENSOR UNIT
610
MONITOR A LOAD POSITION AND A LOAD ORIENTATION OF A LOAD COUPLED WITH THE LOAD LINE, WHEREIN THE MONITORING IS PERFORMED BY A LOAD MONITOR COUPLED WITH THE HOUSING
620
WIRELESSLY PROVIDE INFORMATION FROM THE SENSOR UNIT TO A DISPLAY UNIT LOCATED APART FROM THE SENSOR UNIT, THE INFORMATION INCLUDING THE LOAD POSITION, THE LOAD ORIENTATION, AND THE SENSOR UNIT POSITION
630

FIG. 6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DETERMINE A THREE DIMENSIONAL POSITION OF A COLLISION AVOIDANCE SENSOR UNIT COUPLED WITH A LOAD LINE OF A FIRST LIFTING DEVICE, WHEREIN THE DETERMINING IS PERFORMED BY A FIRST GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) RECEIVER COUPLED WITH A HOUSING OF THE COLLISION AVOIDANCE SENSOR UNIT
710
GENERATE A GEOFENCE FOR THE FIRST LIFTING DEVICE BASED AT LEAST IN PART ON THE COLLISION AVOIDANCE SENSOR UNIT POSITION
720
MONITOR FOR A COLLISION RELATED HAZARD INDICATED BY ENCROACHMENT BETWEEN THE FIRST GEOFENCE AND A SECOND GEOFENCE ASSOCIATED WITH A SECOND LIFTING DEVICE
730
INITIATE AT LEAST ONE COLLISION HAZARD AVOIDANCE ACTION IN RESPONSE TO A MONITORED OCCURRENCE OF THE COLLISION RELATED HAZARD
740
WIRELESSLY PROVIDE THE FIRST GEOFENCE AND THE SECOND GEOFENCE FROM THE COLLISION AVOIDANCE SENSOR UNIT TO A DISPLAY UNIT LOCATED APART FROM THE COLLISION AVOIDANCE SENSOR UNIT
750

FIG. 7

800

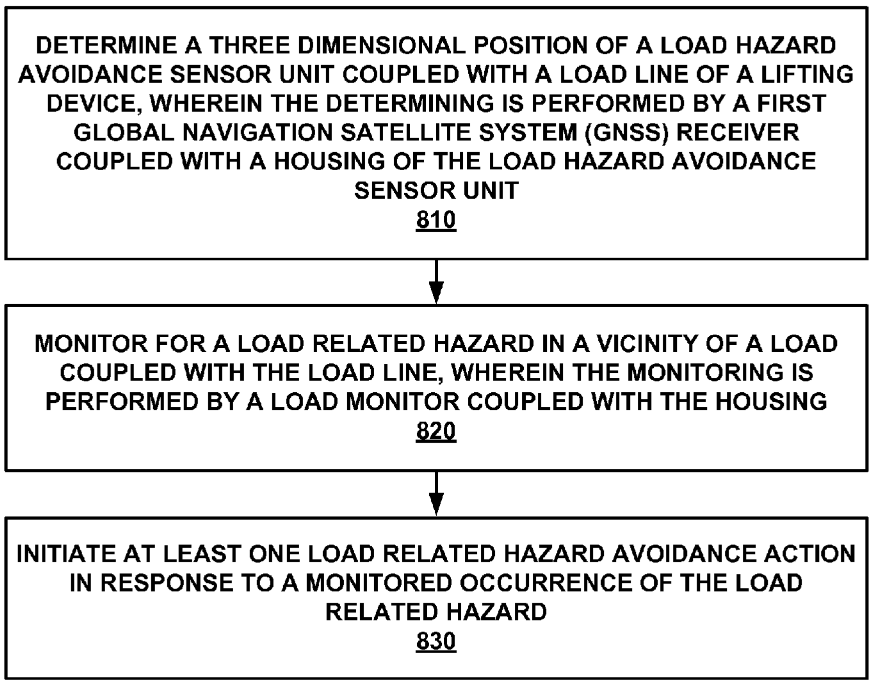
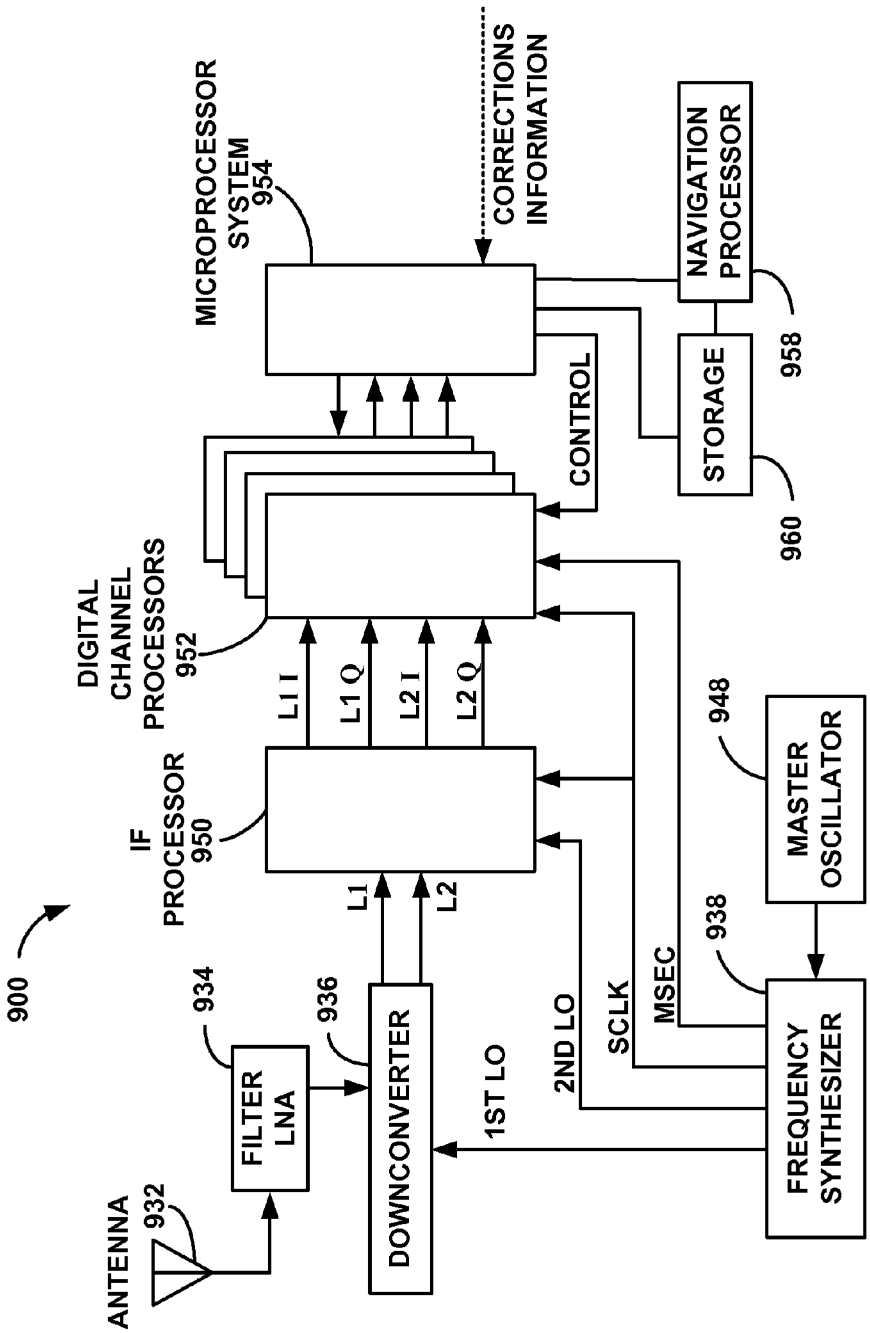

DETERMINE A THREE DIMENSIONAL POSITION OF A LOAD HAZARD AVOIDANCE SENSOR UNIT COUPLED WITH A LOAD LINE OF A LIFTING DEVICE, WHEREIN THE DETERMINING IS PERFORMED BY A FIRST GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) RECEIVER COUPLED WITH A HOUSING OF THE LOAD HAZARD AVOIDANCE SENSOR UNIT
810
MONITOR FOR A LOAD RELATED HAZARD IN A VICINITY OF A LOAD COUPLED WITH THE LOAD LINE, WHEREIN THE MONITORING IS PERFORMED BY A LOAD MONITOR COUPLED WITH THE HOUSING
820
INITIATE AT LEAST ONE LOAD RELATED HAZARD AVOIDANCE ACTION IN RESPONSE TO A MONITORED OCCURRENCE OF THE LOAD RELATED HAZARD
830

FIG. 8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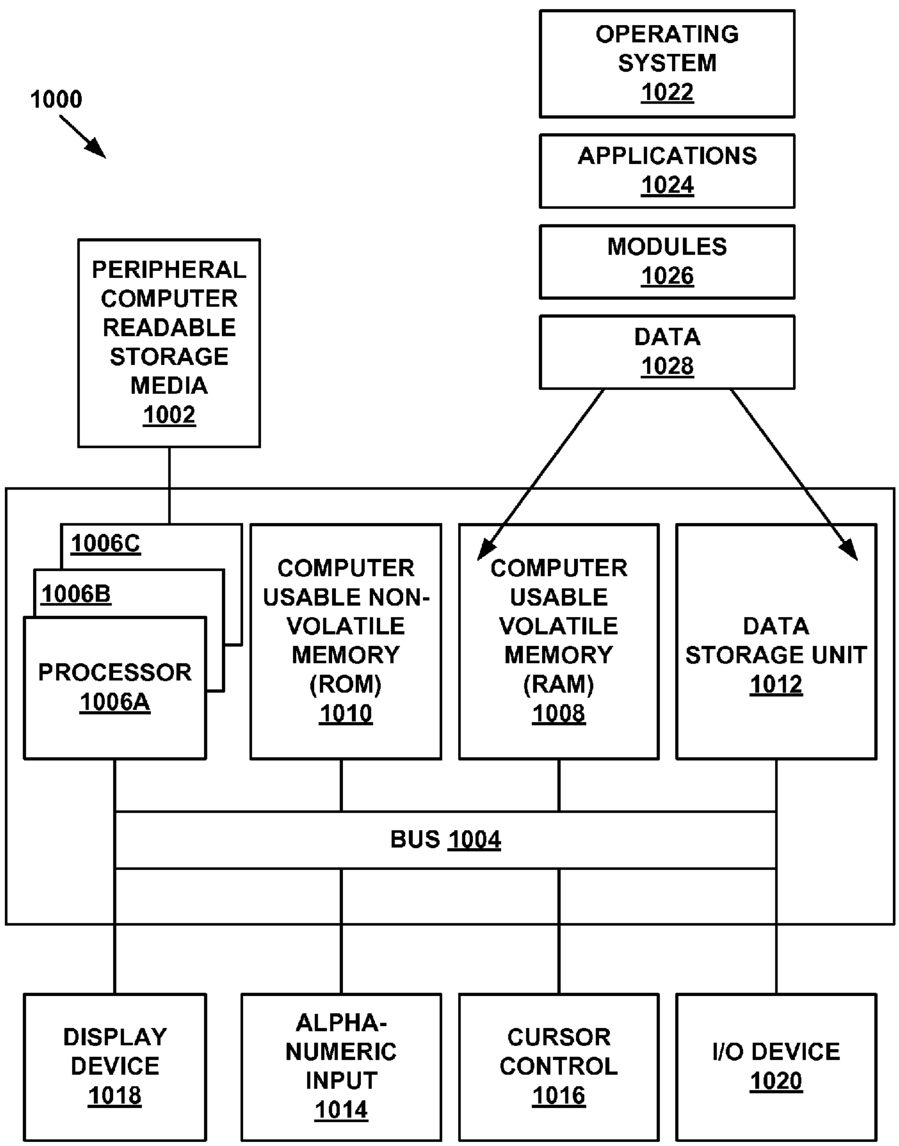
ANTENNA
932
FILTER
LNA
934
DOWNCONVERTER
936
1ST LO
2ND LO
SCLK
MSEC
938
FREQUENCY
SYNTHESIZER
MASTER
OSCILLATOR
948
L1
L2
IF
PROCESSOR
950
L1 I
L1 Q
L2 I
L2 Q
DIGITAL
CHANNEL
PROCESSORS
952
CONTROL
MICROPROCESSOR
SYSTEM
954
CORRECTIONS
INFORMATION
NAVIGATION
PROCESSOR
958
STORAGE
960

FIG. 9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MODULES 1026
DATA 1028
PERIPHERAL COMPUTER READABLE STORAGE MEDIA 1002
1006C
1006B
PROCESSOR 1006A
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COMPUTER USABLE VOLATILE MEMORY (RAM) 1008
DATA STORAGE UNIT 1012
BUS 1004
DISPLAY DEVICE 1018
ALPHA-NUMERIC INPUT 1014
CURSOR CONTROL 1016
I/O DEVICE 1020

FIG. 10

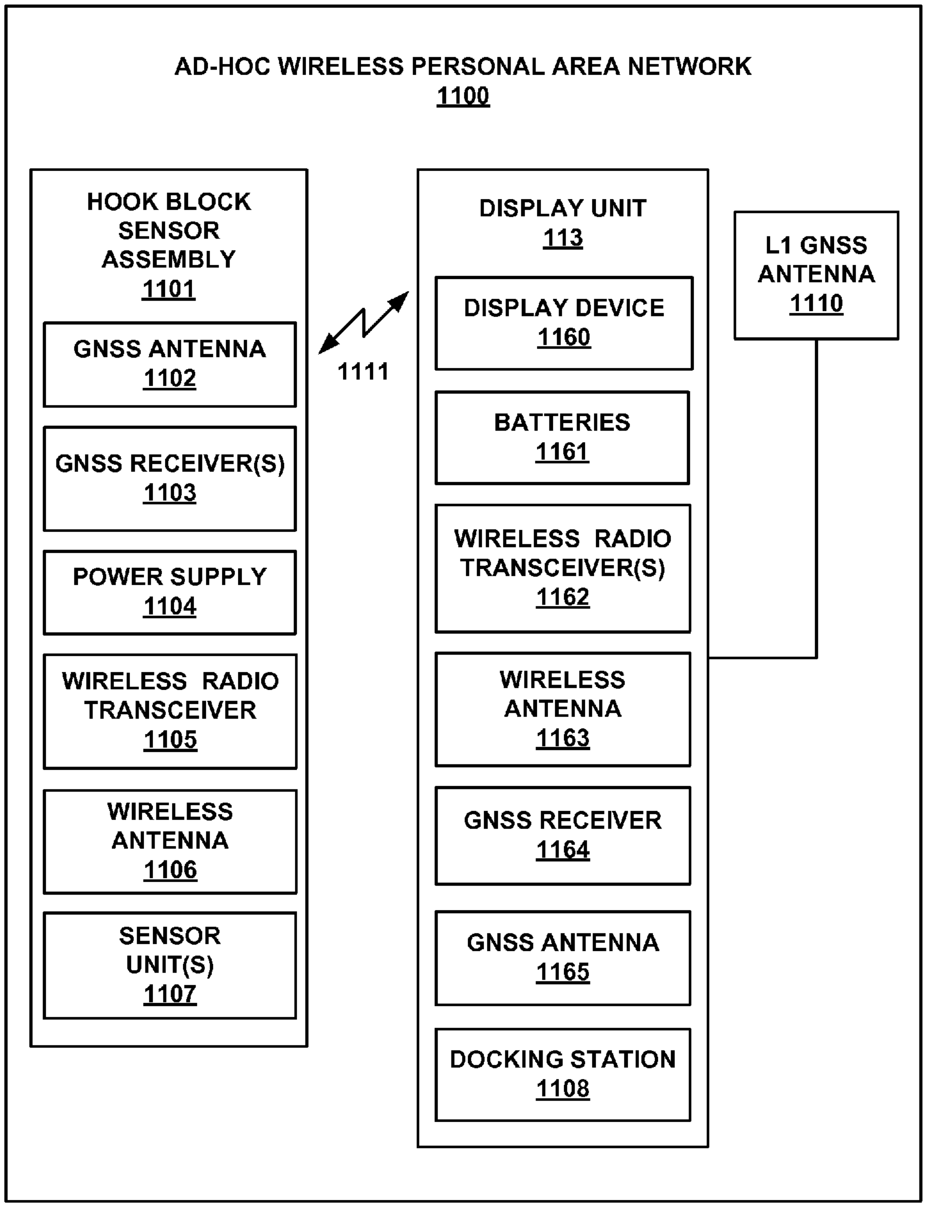
AD-HOC WIRELESS PERSONAL AREA NETWORK
1100
HOOK BLOCK SENSOR ASSEMBLY
1101
GNSS ANTENNA
1102
GNSS RECEIVER(S)
1103
POWER SUPPLY
1104
WIRELESS RADIO TRANSCEIVER
1105
WIRELESS ANTENNA
1106
SENSOR UNIT(S)
1107
1111
DISPLAY UNIT
113
DISPLAY DEVICE
1160
BATTERIES
1161
WIRELESS RADIO TRANSCEIVER(S)
1162
WIRELESS ANTENNA
1163
GNSS RECEIVER
1164
GNSS ANTENNA
1165
DOCKING STATION
1108
L1 GNSS ANTENNA
1110

FIG. 11

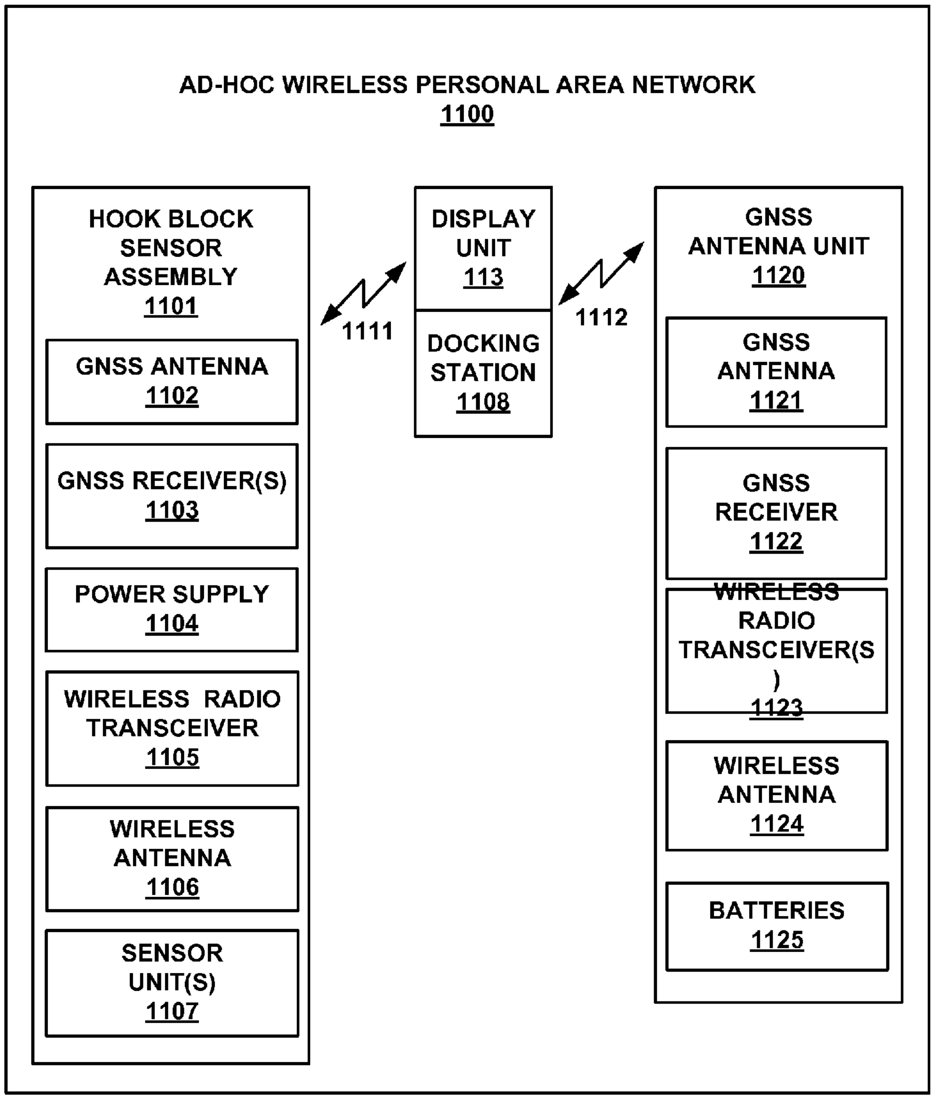
AD-HOC WIRELESS PERSONAL AREA NETWORK
1100
HOOK BLOCK SENSOR ASSEMBLY
1101
GNSS ANTENNA
1102
GNSS RECEIVER(S)
1103
POWER SUPPLY
1104
WIRELESS RADIO TRANSCEIVER
1105
WIRELESS ANTENNA
1106
SENSOR UNIT(S)
1107
1111
DISPLAY UNIT
113
DOCKING STATION
1108
1112
GNSS ANTENNA UNIT
1120
GNSS ANTENNA
1121
GNSS RECEIVER
1122
WIRELESS RADIO TRANSCEIVER(S)
1123
WIRELESS ANTENNA
1124
BATTERIES
1125

FIG. 12

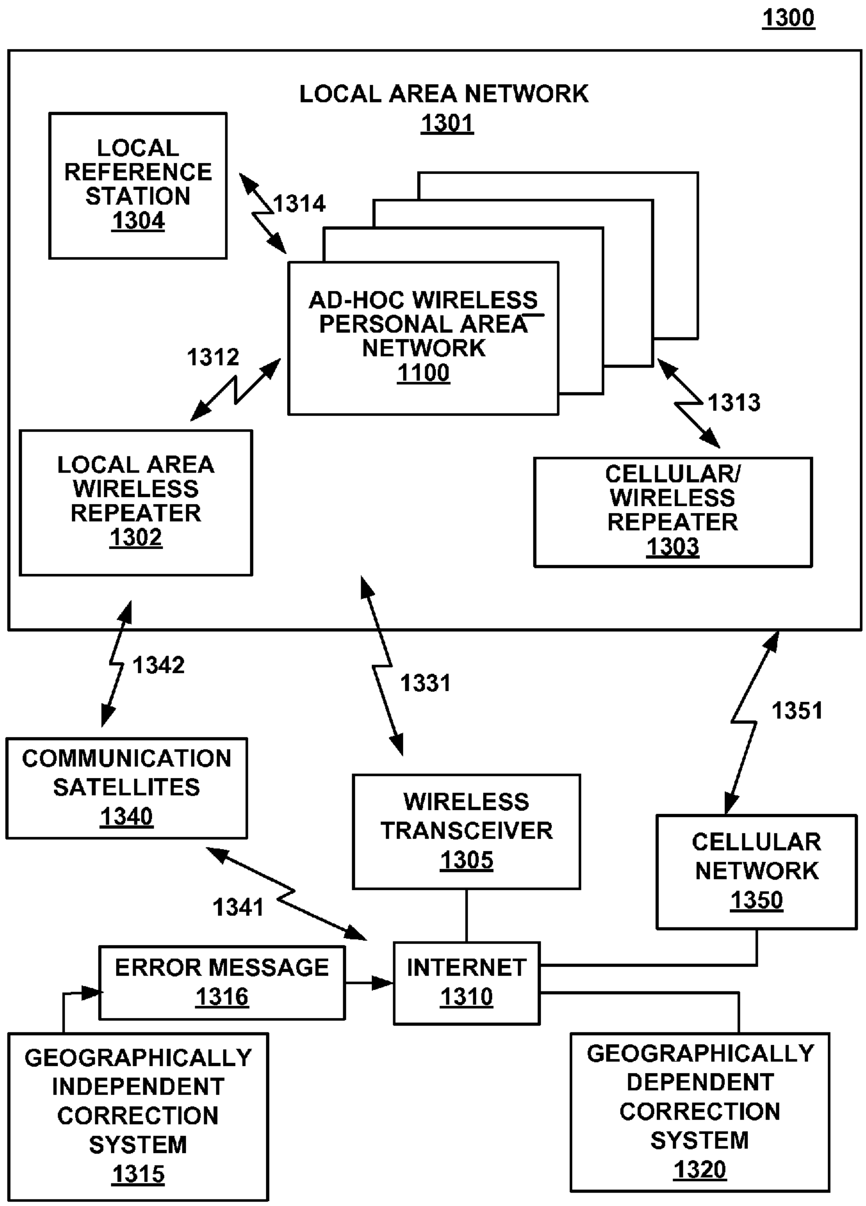
1300
LOCAL AREA NETWORK
1301
LOCAL REFERENCE STATION
1304
1314
AD-HOC WIRELESS PERSONAL AREA NETWORK
1100
1312
1313
LOCAL AREA WIRELESS REPEATER
1302
CELLULAR/ WIRELESS REPEATER
1303
1342
1331
1351
COMMUNICATION SATELLITES
1340
WIRELESS TRANSCEIVER
1305
CELLULAR NETWORK
1350
1341
ERROR MESSAGE
1316
INTERNET
1310
GEOGRAPHICALLY INDEPENDENT CORRECTION SYSTEM
1315
GEOGRAPHICALLY DEPENDENT CORRECTION SYSTEM
1320

FIG. 13

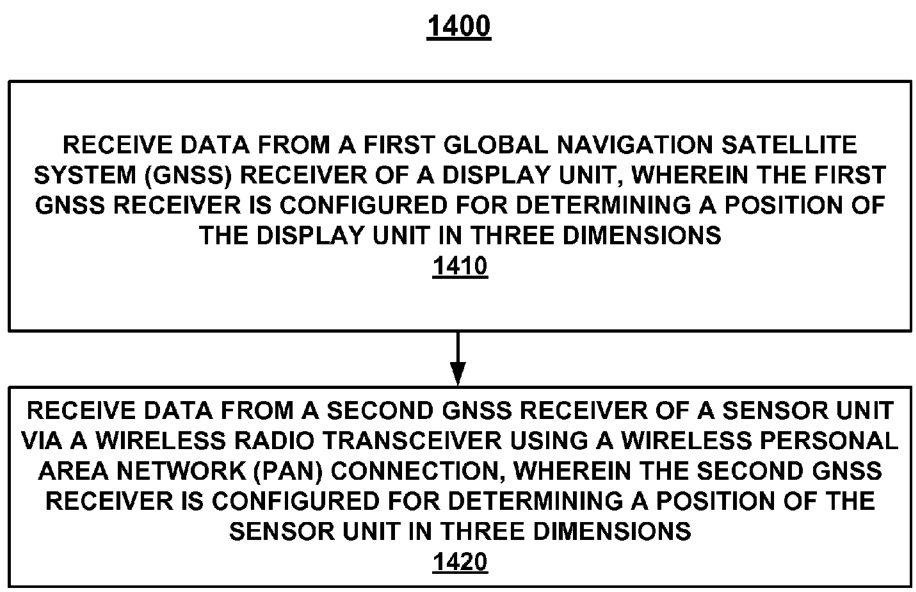
1400
RECEIVE DATA FROM A FIRST GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) RECEIVER OF A DISPLAY UNIT, WHEREIN THE FIRST GNSS RECEIVER IS CONFIGURED FOR DETERMINING A POSITION OF THE DISPLAY UNIT IN THREE DIMENSIONS
1410
RECEIVE DATA FROM A SECOND GNSS RECEIVER OF A SENSOR UNIT VIA A WIRELESS RADIO TRANSCEIVER USING A WIRELESS PERSONAL AREA NETWORK (PAN) CONNECTION, WHEREIN THE SECOND GNSS RECEIVER IS CONFIGURED FOR DETERMINING A POSITION OF THE SENSOR UNIT IN THREE DIMENSIONS
1420

FIG. 14

LIFTING DEVICE EFFICIENT LOAD DELIVERY, LOAD MONITORING, COLLISION AVOIDANCE, AND LOAD HAZARD AVOIDANCE

CROSS-REFERENCE TO RELATED U.S. APPLICATIONS-DIVISIONAL

This application is a divisional application of and claims the benefit of co-pending U.S. patent application Ser. No. 13/017,232 filed on Jan. 31, 2011, entitled "Lifting Device Efficient Load Delivery, Load Monitoring, Collision Avoidance, and Load Hazard Avoidance" by Kurt Maynard et al., and assigned to the assignee of the present application; the disclosure of which is hereby incorporated herein by reference in its entirety.

The application with Ser. No. 13/017,232 filed on Jan. 31, 2011, entitled "Lifting Device Efficient Load Delivery, Load Monitoring, Collision Avoidance, and Load Hazard Avoidance" by Kurt Maynard et al., claims the benefit of and claims priority to provisional patent application Ser. No. 61/300,360, entitled "LIFTING DEVICE EFFICIENT LOAD DELIVERY, LOAD MONITORING, COLLISION AVOIDANCE, AND LOAD HAZARD AVOIDANCE," with filing date Feb. 1, 2010, assigned to the assignee of the present application; provisional patent application 61/300,360 was incorporated by reference in its entirety into application Ser. No. 13/017,232. This application claims priority to and benefit of provisional patent application 61/300,360 through patent application Ser. No. 13/017,232.

CROSS-REFERENCE TO RELATED U.S. APPLICATIONS

This application is also related to co-pending U.S. patent application Ser. No. 13/017,320 filed on Jan. 31, 2011, entitled "Sensor Unit System" by Kurt Maynard et al., and assigned to the assignee of the present application.

This application is also related to co-pending U.S. patent application Ser. No. 13/708,843 filed on Dec. 7, 2012, entitled "Sensor Unit System" by Gregory C. Best et al., and assigned to the assignee of the present application.

This application is also related to co-pending U.S. patent Divisional application Ser. No. 14/088,167 filed on Nov. 22, 2013, entitled "Lifting Device Efficient Load Delivery, Load Monitoring, Collision Avoidance, and Load Hazard Avoidance" by Kurt Maynard et al., and assigned to the assignee of the present application.

This application is also related to co-pending U.S. patent Divisional application Ser. No. 14/088,179 filed on Nov. 22, 2013, entitled "Lifting Device Efficient Load Delivery, Load Monitoring, Collision Avoidance, and Load Hazard Avoidance" by Kurt Maynard et al., and assigned to the assignee of the present application.

This application is also related to co-pending U.S. patent Continuation application Ser. No. 14/088,206 filed on Nov. 22, 2013, entitled "Lifting Device Efficient Load Delivery, Load Monitoring, Collision Avoidance, and Load Hazard Avoidance" by Kurt Maynard et al., and assigned to the assignee of the present application.

This application is also related to co-pending U.S. patent Continuation application Ser. No. 14/088,214 filed on Nov. 22, 2013, entitled "Lifting Device Efficient Load Delivery, Load Monitoring, Collision Avoidance, and Load Hazard Avoidance" by Kurt Maynard et al., and assigned to the assignee of the present application.

BACKGROUND

When using a lifting device, such as for example, a crane, it is often very difficult or impossible for an operator to see the area around and below the load that is being lifted, moved, or positioned by the lifting device. As but one example, some lifts are blind to an operator of the lifting device, such as when a load is dropped into a hole. As such, it is difficult and sometimes dangerous to perform lift activities. This is because the lifting device operator cannot see the position of the load, and the hazards that might hit or be hit by the load. Even routine lifts, where a lifting device operator can view the load, can be complicated by diminished situational awareness regarding the position of the load and/or potential hazards in the vicinity of the load.

Additionally, a job site or work area often has more than one lifting device in operation at any given time. As lifting devices are often in movement and require immense concentration to operate, it can be difficult for an operator to constantly determine if there is adequate clearance to prevent collision of some portion of his lifting device or load with a portion of another lifting device or another lifting device's load.

Furthermore, having real time knowledge of the absolute position and orientation of the load, in coordination with a mapped or modeled job site, can facilitate and increase the efficiency of delivering this load to the coordinates of the desired destination.

SUMMARY

A lifting device sensor unit is disclosed. In one embodiment, the sensor unit comprises a housing configured to removably couple about a load line of a lifting device. A first global navigation satellite system (GNSS) receiver is coupled with the housing and is configured for determining a sensor unit position in three dimensions. A load monitor is coupled with the housing and is configured for monitoring a load coupled with the load line, including monitoring a load position and a load orientation of the load. A wireless transceiver is coupled with the housing and is configured for wirelessly providing information including the load position, the load orientation, and the sensor unit position, to a display unit located apart from the sensor unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of this application, illustrate embodiments of the subject matter, and together with the description of embodiments, serve to explain the principles of the embodiments of the subject matter. Unless noted, the drawings referred to in this brief description of drawings should be understood as not being drawn to scale.

FIG. 1A is a diagram of an example lifting device sensor system in place on a lifting device, in accordance with an embodiment.

FIG. 1B shows an alternative coupling of a sensor unit of the sensor system with a lifting device load line, in accordance with an embodiment.

FIG. 2A is a diagram of a selection of sensor unit components coupled with a housing of a sensor unit, in accordance with an embodiment.

FIG. **2**B illustrates a selection of features of a lifting device sensor unit, in accordance with various embodiments

FIG. **2**C illustrates an example load line positioner coupled with a housing of a sensor unit, in accordance with an embodiment.

FIG. **2**D illustrates an example sensor unit coupled with a hook block, in accordance with various embodiments.

FIG. **3** is a block diagram of additional lifting device sensor unit components that may variously be included in a lifting device sensor unit, according to one or more embodiments.

FIG. **4** illustrates a display of an example lift plan that has been generated by a lifting device sensor unit, according to an embodiment.

FIG. **5** illustrates a display of example lifting device geofence information that has been generated by one or more lifting device sensor units, according to an embodiment.

FIG. **6** is a flow diagram of an example method of monitoring a lifting device load, in accordance with an embodiment.

FIG. **7** is a flow diagram of an example method of lifting device collision, in accordance with an embodiment.

FIG. **8** is a flow diagram of an example method of lifting device load hazard avoidance, in accordance with an embodiment.

FIG. **9** shows an example GNSS receiver that may be used in accordance with some embodiments.

FIG. **10** illustrates a block diagram of an example computer system with which or upon which various embodiments of the present invention may be implemented.

FIG. **11** is a block diagram of an example ad-hoc wireless personal area network in accordance with one or more embodiments.

FIG. **12** is a block diagram of an example ad-hoc wireless personal area network in accordance with one or more embodiments.

FIG. **13** is a block diagram of an example communication network in accordance with one or more embodiments.

FIG. **14** is a flowchart of a method for communicatively coupling a sensor unit system in accordance with one or more embodiments.

DESCRIPTION OF EMBODIMENTS

Reference will now be made in detail to various embodiments, examples of which are illustrated in the accompanying drawings. While the subject matter will be described in conjunction with these embodiments, it will be understood that they are not intended to limit the subject matter to these embodiments. On the contrary, the subject matter described herein is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope as defined by the appended claims. In some embodiments, all or portions of the electronic computing devices, units, and components described herein are implemented in hardware, a combination of hardware and firmware, a combination of hardware and computer-executable instructions, or the like. Furthermore, in the following description, numerous specific details are set forth in order to provide a thorough understanding of the subject matter. However, some embodiments may be practiced without these specific details. In other instances, well-known methods, procedures, objects, and circuits have not been described in detail as not to unnecessarily obscure aspects of the subject matter.

Notation and Nomenclature

Unless specifically stated otherwise as apparent from the following discussions, it is appreciated that throughout the present Description of Embodiments, discussions utilizing terms such as "determining," "monitoring," "providing," "initiating," "generating," "wirelessly communicating," "wirelessly acquiring," "wirelessly providing," "accessing," "communicating," or the like, often (but not always) refer to the actions and processes of a computer system or similar electronic computing device such as, but not limited to, a display unit and/or a lifting device sensor unit or component thereof. The electronic computing device manipulates and transforms data represented as physical (electronic) quantities within the electronic computing device's processors, registers, and/or memories into other data similarly represented as physical quantities within the electronic computing device's memories, registers and/or other such information storage, processing, transmission, or/or display components of the electronic computing device or other electronic computing device(s).

The term "lifting device" is used often herein. By "lifting device" what is meant is a device that utilizes a load line to lift a load. Some non-limiting examples of lifting devices include a jib crane, gantry crane, derrick crane, boom crane (telescoping or fixed), wheel mounted crane, truck mounted crane, crawler mounted crane, overhead crane, monorail carrier, straddle crane, tower crane, crane with a hoist but no boom, and a hoist. Typically a lifting device lifts a load with a hook or some attachment point located at a distal end/position of the load line with respect to a lifting point or arm to which it is attached. A load line is typically a cable, but in some a load line may comprise chain, rope, more than one cable, multiple sections of a single or multiple cables, or some combination thereof.

Overview of Discussion

Example units, systems, and methods for lifting device efficient load delivery, load monitoring, collision avoidance, and load hazard avoidance are described herein. Discussion begins with description of lifting device sensor unit and system shown coupled with two example lifting devices. Discussion continues with description of various components of an example sensor unit that may be used for one or more of: assisting in efficient load delivery, load monitoring, collision avoidance, and load hazard avoidance. Techniques of object identification in the vicinity of the load are described. Example displays of a lift plan and lifting device geofences are then discussed. Example methods of operation are discussed. Discussion then turns to description of an example GNSS receiver which may be used in various portions of the sensor unit and sensor system. An example computer system is then described, with which or upon which various components, method procedures, or portions thereof may be implemented. Implementations of an ad-hoc wireless personal area network are then discussed. Finally, an example communication network is described.

Example Lifting Device Sensor System

FIG. **1**A is a diagram of an example lifting device sensor system **100** in place on a lifting device **120**, in accordance with an embodiment. Lifting device sensor system **100** can be used to assist in or accomplish one or more of efficient load delivery, load monitoring, collision avoidance, and load hazard avoidance. It is appreciated that two or more of these functions may often overlap. In one embodiment, lifting device sensor system **100** comprises sensor unit **110** and one or more display units **113**. Dashed lines **115**A and **115**B indicate wireless communication that occurs or can occur between sensor unit **110** and display unit(s) **113**. Display unit

113 may be a dedicated display with a wireless transceiver or may be part of an electronic device such as smart phone, netbook, notebook computer, tablet computer, or the like. It is appreciated that sensor unit **110** is referred to herein in the generic sense as "sensor unit" or "lifting device sensor unit," and more particularly as "lifting device collision avoidance sensor unit," or "lifting device load hazard avoidance sensor unit." In some embodiments lifting device sensor system **100** further comprises: one or more global navigation satellite receivers (e.g., **108**, **107**) which are or may be coupled to portions of a lifting arm or a body of a lifting device, such as lifting device **120**; and/or one or more object identifiers **102** that may be coupled to objects in a working area of lifting device **120**. As will be discussed in greater detail below, in one embodiment, inertial sensors (e.g., **214** of FIG. **2**A) of sensor unit **110** can be used to augment, or work in conjunction with, the GNSS receivers **107** and **108** and/or sensor unit **110** to provide lifting device sensor system **100** with positioning data. For example, during periods when the view to GNSS satellites may be temporarily obstructed, the inertial sensors can provide positioning data which permits lifting device sensor system **100** to continue determining the position of sensor unit **110** and/or portions of lifting device **120**. As will be further described herein, in various embodiments sensor unit **110** is removably couplable with load line **112**, other load lines of similar or different cross-sectional dimensions, and other load lines of similar or different configurations.

In FIG. **1**A, GNSS receiver **108** is coupled to counter-weights on the body (i.e., not on the lifting arm) of lifting device **120** and determines a position of point **143** in two or three dimensions. GNSS receiver **107** is coupled near the distal tip region of lifting arm **119** (a boom in this case) and determines a position of point **153** in two or three dimensions. It is appreciated that one or more of GNSS receivers **107** and **108** may wired or wirelessly communicate their determined positions (e.g., the positions of points **153** and **143**) to operator cab **121** or to a component in operator cab **121** such as cab mounted display **113**A. One such communication is illustrated by **109**. Such positions may also be wirelessly communicated to components of sensor system **100**, such as hand-holdable display unit **113**B and/or sensor unit **110**. Likewise, load information determined load cell **122** and/or lifting arm angle information determined by angle sensor/inclinometer **116** may be communicated to one or more components of sensor system **100** in the same or similar manner.

In FIG. **1**A, object identifiers **102**A and **102**B are coupled to load **104** and identify information about load **104**. Among other things, the information provided by load mounted objected identifiers may include information such as: what load **104** is (e.g., an I-beam); the orientation of load **104** (e.g., where the sides/ends are and/or which side/end belongs where at a final destination); and/or the lift destination for load **104**. Object identifier **102**C is located on the cap of person **117**A and object identifier **102**D is located on the helmet of person **117**B. In various embodiments object identifiers may comprise mechanisms such as: Radio Frequency Identifiers (RFIDs); reflectors; bar codes; or some mix or combination thereof. Object identifiers facilitate identification, location, and/or tracking of one or more objects in the vicinity of a load in the viewing region beneath sensor unit **110**. It is noted that in one embodiment, due to the nature of the components (e.g., positioning and communications technology) typically found on modern "smart" cellular telephones and Personal Digital Assistants (PDAs), the capability of providing an object identifier (e.g., object identifier **102**C and **102**D of FIG. **1**A) can be provided using a cellular telephone, PDA, or similarly configured portable electronic having a suitable software application loaded onto it which enables it to be a part of, or communicatively coupled with, lifting device sensor system **100**.

With continued reference to FIG. **1**A, lifting device **120** includes an operator cab **121** from which an operator manipulates controls to lift a load **104** with lifting arm **119**. In some embodiments, a lifting device that is configured differently than lifting device **120** may not include a cab, but may instead be operated with a handheld control box or in some other manner. Lifting device **120**, in some embodiments, also includes one or more of: an angle sensor/inclinometer **116** for measuring an angle of lifting arm **119**; and a load cell **122** for monitoring the presence, absence, and or weight of a load **104** on load line **112**. As illustrated in FIG. **1**A, rigging **105** is used to couple load **104** with a hook **111** located at a distal end of load line **112**.

In FIG. **1**A, point **133** represents a three dimensional position of sensor unit **110** that has been determined by a GNSS receiver (e.g., GNSS receiver **213**A of FIG. **2**) disposed in. Point **134** represents a three dimensional position of or on load **104** that has been determined by sensor unit **110**. In some embodiments, a GNSS receiver (e.g., GNSS receiver **213**A or **213**B of FIG. **2**A) of sensor unit **110** also determines an angular orientation **135** of point **133** or some other point on sensor unit **110**. Such an angular orientation identifies a swinging component of sensor unit **110** that can occur as a result of sensor unit **110** being coupled with load line **112**.

FIG. **1**B shows an alternative coupling of sensor unit **110** of the sensor system **100** with a lifting device load line **112**, in accordance with an embodiment. It is appreciated that FIG. **1**B also illustrates only one of one of several other techniques for coupling a hook **111** or attachment point with a load line **112**. In FIG. **1**B, an end of load line **112** is fixedly coupled to lifting arm **119** at attachment point **171**. Hook **111** is coupled with a pulley **170** that moveably rides upon load line **112** and is located at a gravity determined distal position (with respect to lifting arm **119**) on load line **112**.

FIG. **2**A is a diagram of a selection of sensor unit components coupled with a housing **201** of sensor unit **110**, in accordance with an embodiment. As illustrated, in one embodiment, sensor unit **110** includes one or more GNSS receivers **213**, one or more power sources **217**, one or more load monitors **214**, and one or more wireless transceivers **215**. In some embodiments sensor unit **110** may also include one or more additional sensor unit components **216** (further described in FIG. **3**). These components of sensor unit **110** are communicatively and/or electrically coupled with one another as required for performing functions of load monitoring, collision avoidance, and/or load hazard avoidance.

Housing **201** is configured to removably couple about a load line **112** of a lifting device. As depicted, this comprises housing **201** coupling about load line **112** at a location between load hook **111** (or other type of load attachment point in other embodiments) and the location where load line **112** meets the lifting device. In depicted embodiments housing **201** is substantially spherical, however other shapes are possible. Housing **201** is comprised of a rigid or semi-rigid material or materials. In one embodiment, all or a portion of housing **201** is made of an injection molded material such as high impact strength polycarbonate. In one embodiment at least a portion of housing **201** is transparent to GNSS satellite signals such that these signals can be received by GNSS receiver(s) **213**A, **213**B, which are couple with housing **201** and secured inside housing **201**. In some embodiments housing **201** comprises a plurality of sections (e.g., hemispheres **201**A, **201**B) that join, fasten, latch, or otherwise couple with one another to form housing **201** and to removably couple about load line **112**. Although two sections (hemispheres **201**A, **201**B) are illustrated, some embodiments may include more. As illustrated in FIG. **2**A, hemispheres **201**A and **201**B removably couple with one another at joint **202**.

Although housing **201** of sensor unit **110** is shown as being positioned above hook **111** on load line **112**, in some embodiments, some of all of the functions/components of a sensor unit **110** may be built into or housed in lifting hook **111** or similar load attachment point/mechanism located on a distal end/portion of load line **112**. One example of such an embodiment, is depicted in FIG. **2**D.

With continued reference to FIG. **2**A, the removably couplable characteristic of housing **201** facilitates field mounting and removal of sensor unit **110**. In this manner, a construction company or crane rental company, for example, can flexibly utilize sensor unit **110** with a plurality of different lifting devices by moving sensor unit **110** from one lifting device load line to a load line of another lifting device. The removably couplable characteristic of housing **201** also facilitates the use of sensor unit **110** on lifting devices from a variety of manufacturers as no permanent mounting, hardwiring to the electrical system of the lifting device, or interfacing with the operating system of the lifting device is required.

Load monitor **214** (**214**A, **214**B illustrated) are coupled with housing **201** and monitor a load **104** coupled with load line **112**. This monitoring includes monitoring a load position and/or a load orientation of load **104**. A load monitor may be a camera (e.g., a digital camera), a plurality of cameras, an ultrasonic sensor, a laser scanner, a bar code scanner, a radio frequency identification device transceiver, an inertial sensor (e.g., a gyroscope, accelerometer, mechanical accelerometer, an electro-mechanical accelerometer such as a Micro-Electro-Mechanical System (MEMS, etc.), or some combination of these. Load monitor(s) **214** typically face downward from sensor unit **110** toward load hook **111** to attain a field of view **218** (**218**A, **218**B illustrated) that encompasses at least a portion of load **104** and typically some area in the surrounding vicinity of load **104**. Through the use of object identifiers **102** (as illustrated in FIG. **1**A), a load monitor **214** can track and locate object(s) marked with one or more object identifiers **102** as such objects enter or depart from a field of view **218**. In some embodiments load monitor **214** performs ranging or positioning through use of photogrammetry, laser scanning, and/or ultrasonic measurement techniques in order to measure ranges to/and locations of objects in a field of view **218**. In some embodiments, ranges/positions of objects in a field of view **218** are determined as an offset from a known three dimensional position of point **133** of sensor unit **110**. In this manner, one or more positions with respect to a sensor unit **110** can be determined FIG. **1**A illustrates one point **134**, on load **104**, for which a position has been determined in this fashion. However, in some embodiments, additional ranges/positions can be determined For example, the ranges/positions of object identifiers **102**A, **102**B, **102**C, and or **102**D, can be determined when they are within one or more fields of view **218**. Inertial sensors are used in one embodiment to augment, or work in conjunction with, the GNSS receivers **213** in determining the position of sensor unit **110** in three dimensions. The use of inertial sensors in sensor unit **110** allows lifting device sensor system **100** to continue positioning functions for periods of time when the view of GNSS satellites may be temporarily obstructed. The inertial sensors may also provide motion detection of sensor unit **110** for the purpose of initiating a shut-down sequence of one or more components of lifting device sensor system **100** to preserve their battery life when it is determined that sensor unit **110** has not moved for a selected period of time (e.g., five minutes, ten minutes, etc.). Alternatively, one or more of GNSS receivers **213** can be used to determine that sensor unit **110** has not moved for a period of time for the purpose of shutting down components of lifting device sensor system **100** to preserve their battery life.

In one embodiment, a load monitor **214** also monitors for load related hazards in a vicinity of load **104**. A load related hazard is an object that is at risk of impacting with or being impacted by load **104**. Such monitoring can be accomplished using range or position information that is determined regarding respective objects in one or more fields of view **218**. Such objects may or may not be labeled with object identifiers **102**. In some embodiments, load monitor **214** additionally or alternatively utilizes techniques such as facial recognition and/or infrared sensing to discern and monitor for persons **117** within a field of view **218**.

It is appreciated that a field of view **218**, and even overlapping fields of view (e.g., **218**A, **218**B, etc.), may have a blind spot beneath a load **104**. In one embodiment, a load related hazard that may be monitored for is the loss of view, in or near the blind spot, of an object identifier (e.g., **102**C, **102**D as illustrated in FIG. **1**A) associated with a person **117** or other object, or the loss of view of a person **117** that has been identified and monitored by other means.

Wireless transceiver **215** is coupled with housing **201**. Wireless transceiver **215** may operate on any suitable wireless communication protocol including, but not limited to: WiFi, WiMAX, 802.11 family, cellular, two-way radio, and mesh networking. In one embodiment wireless transceiver **215** wirelessly provides information such as one or move of: load position (e.g., the position of point **134**), load orientation, and/or a sensor unit position (e.g., the position of point **133**) to a display unit **113** located apart from sensor unit **110**. It is appreciated that other forms of information including, but not limited to, images, photos, video, lift plans, other object range/position information, object identification information, geofence information, collision alerts, and load hazard alerts can be provided wirelessly provided to a display unit **113** located apart from sensor unit **110**. In some embodiments, wireless transceiver **215** communicates with one or more other sensor unit coupled with lifting devices that are within communication range. In some embodiments, wireless transceiver **215** communicates with one or more sensors or devices that are coupled with a lifting device, such sensors and devices include but are not limited to: a GNSS receiver (e.g., **107**, **108**, etc.), an angle sensor/inclinometer **116**, and a load cell **122**. For example, by communicating with load cell **122**, load monitor **214** can receive information indicative of whether or not lifting device **120** has taken on or released a load **104**. In some embodiments, this will allow load monitor **214** or other component(s) of sensor unit **110** to enter a low power energy conservation mode when a load **104** is not present in order to conserve power in power source(s) **217**.

With continued reference to FIG. **2**A, one or more power sources **217**A, **217**B are located inside housing **201**. These power sources **217**A, **217**B couple with housing **201**, and configured for providing electrical power for operating electrical components of sensor unit **110**. These power sources **217** may comprise batteries, capacitors, or a combination thereof. Additionally, as described further below, these power sources **217** may be recharged by means of recharging contacts located on or accessible through the exterior surface of housing **201**; and may be recharged by a power source charger that is coupled with housing **201** (as a part of sensor unit **110**) and generates electrical power (e.g., through motion of sensor unit **110**, through solar power production, or by other suitable power generation process).

FIG. **2**B illustrates a selection of features of a lifting device sensor unit **110**, in accordance with various embodiments. The features illustrated in FIG. **2**B are located on or are accessible via the external surface of housing **201**. This selection of features includes: a sound emitting device **251** (e.g., a speaker, siren, horn, or the like); a light emitting device **252** (e.g., a light bulb, strobe, light emitting diode, or the like); an access hatch **253**; recharge contacts **254**; and/or a protective bumper **255**. Some, all, or none of these features may be included in embodiments of sensor unit **110**. In one embodiment, light emitting device **252** comprises an array of status indicator lights such as Light Emitting Diodes (LEDs) which can be used to convey status information to an operator of lifting device **120**.

In one embodiment, access hatch **253** provides easy access to components that are located in an internal portion of sensor unit **110**. In some embodiments, access hatch **253** is a power source access hatch that facilitates access to power source(s) **217**, to facilitate recharge, removal, and/or replacement of power source(s) **217** while sensor unit **110** remains coupled with load line **112**. This allows some routine maintenance or internal access without requiring removal of sensor unit **110** from load line **112** or decoupling of housing portions **201**A and **201**B from one another.

Recharge contacts **254** facilitate recharge of power source(s) **217** without requiring removal of sensor unit **110** from load line **112** or decoupling of housing portions **201**A and **201**B from one another. For example, a person may attach charging leads to recharge contacts **254**, or charging leads may automatically engage with recharge contacts **254** when sensor unit **110** is placed in a docked state. With reference to lifting device **120**, in one embodiment, a docked state may be achieved by raising sensor unit **110** until it makes encounters a stop at lifting arm **119** where a dock or charging leads may reside. In other embodiments, when used with different types of lifting devices, a docked state may not be achievable or may be achieved in a different manner.

Protective bumper **255** extends from a portion of the external surface of housing **201** and provides a limited amount of impact protection for sensor unit **110**. In some embodiments, protective bumper **255** may serve an additional purpose of securing or assisting in securing closure of portions (e.g., **201**A, **201**B) of housing **201**. Protective bumper **255** may be slidably emplaced on housing **201** and held in place by friction and/or elastive force. Protective bumper **255** may also be latched or secured in place on housing **201**.

FIG. **2**C illustrates an example load line positioner **261** coupled with a housing **201** of sensor unit **110**, in accordance with an embodiment. In one embodiment, load line positioner **261** comprises an arrangement of a plurality of pinch rollers/motors **261**A, **261**B, **261**C to both hold sensor unit **110** in a particular place on load line **112** and to facilitate controllable and adjustable movement and positioning of sensor unit **110** along load line **112** (as indicated by the bi-directional arrow). Such movement, in one embodiment is controlled by position control **320** (FIG. **3**) and may occur automatically in accordance with predefined criteria or in accordance with an input wirelessly received by sensor unit **110** (such as from a display unit **113** in response to a user input).

Movement of sensor unit **110** along load line **112** allows load monitor(s) **114** to monitor load **104** and take measurements from different locations. This can assist in photogrammetry and in other techniques used for determining range and/or position of objects in field of view(s) **218**. Moreover, in performance of some lifts, it may be advantageous to move the sensor unit **110** in order for it to maintain reception of GNSS signals that would otherwise be shielded or blocked by objects in the lift area. Additionally, loads of large size may require the sensor unit **110** to be moved upward so that larger field(s) of view **218** around load **104** can be achieved than would be possible with sensor unit **110** in closer proximity to load **104**. For example, it may be easy to get a field of view on sides of an I-beam with the sensor unit **110** located near the I-beam, but difficult to get a field on sides of a large panel, pallet, or container that block portions of the field of view from the same position of sensor unit **110**. Additional movement of sensor unit **110** may occur in situations where the lifting device **120** uses a pulley type arrangement for securing hook **111** to load line **112** (as illustrated in FIG. **1**B).

FIG. **2**D illustrates an example sensor unit **110** coupled with a hook block **111**, in accordance with various embodiments. As in FIGS. **2**A and **2**D, sensor unit **110** includes a housing **201** with which or within which, the various components and sensors of sensor unit **110** may be coupled. It is appreciated that one or more of the various features described in conjunction with FIG. **2**A and FIG. **2**B may be included in the sensor unit and housing thereof which are depicted in FIG. **2**D. Although depicted as spherical, housing **201** of FIG. **2**D, may be of other shapes. Additionally, although depicted as being disposed in the midst of load hook **111**, sensor unit **110** and its housing **201** may be disposed between load line **112** and hook **111**, in some embodiments or fully integrated within hook **111**. The combination of hook **111** and sensor **110**, as depicted in FIG. **2**D, is one example of a hook block sensor assembly (e.g., hook block sensor assembly **1101**, which is described in conjunction with FIG. **11**). Though not illustrated in FIG. **2**D, in some embodiments, hook **111** may be integrated with one or more pulleys such that cable **112** may be coupled with two or more points of a lifting arm **119** (see e.g., FIG. **1**B, for one such example).

FIG. **3** is a block diagram of additional lifting device sensor unit components **216** that may be variously included in a lifting device sensor unit **110**, according to one or more embodiments. These additional sensor unit components may include one or more of a lift plan generator **305**, a collision monitor **310**, an avoidance action initiator **315**, a position control **320**, and a power source charger **325**.

Lift plan generator **305** generates a lift plan for efficiently lifting and/or safely lifting a load **104** to a destination associated with said load. Following such a lift plan, rather than having an operator "eyeball" a lift from scratch with no lift plan can reduce accidents and in many cases speed lifting, thus improving productivity. In one embodiment, lift plan generator **305** utilizes identified information regarding a load to ascertain where its destination is on a job site. Other information such as a destination orientation of a load **104** may be ascertained. Such information can be discerned based on one or more object identifiers **102** that may be coupled with a load **104** and may include this information, such as in an RFID memory or may provide a identifier associated with the load which can be used for looking up or accessing such load destination information from a job site schematic or virtual plan. Lift plan generator **305** may additionally or alternatively take into account known (e.g., mapped such as in a virtual site plan or previously recognized by sensor unit **110**) objects and hazards which are in the vicinity of the lift, such that these hazards are safely avoided in the generated lift plan. In this fashion, based on the virtual plan of a site and/or objects that load monitor **214** has mapped, the lift plan is generated such that an efficient path is outlined which does allows the load to avoid known hazards between the start and destination of the lift. In one embodiment wireless transceiver **215** provides this lift plan to a display unit **113** for display to a user during the lift. Lift plan generator **305** can also be used when multiple lifting devices **120** are used to lift and/or move a single shared load. In one embodiment, a separate lift plan generator **305** is implemented on each of the lifting devices **120** that are coordinating their efforts to lift and/or move a single shared load and generates commands to control the operation of its respective lifting device **120** such that the single shared load can be lifted and/or moved safely and efficiently. In one embodiment, communication between sensor unit **110** can be sent to multiple display units **113**A and **113**B to coordinate implementation of lifting and/or moving of a single shared load, or communication between multiple sensor units **110** can be sent to a single display unit **113**A or **113**B to coordinate implementation of lifting and/or moving of a single shared load. Similarly, communication between multiple sensor units **110** can be sent to multiple display units **113**A and **113**B to coordinate implementation of lifting and/or moving of a single shared load.

FIG. **4** illustrates a display of an example lift plan **400** that has been generated by a lifting device sensor unit **110**, according to an embodiment. Lift plan **400** includes a top plan view **410** and a side elevation view **420** of the lift path of load **104** from an initial location **401** to a destination location **402**. It is appreciated that, in some embodiments, additional or different views of the lift path of a load may be generated by lift plan generator **305**. It is also appreciated that, in some embodiments, all or a portion of lift plan **400** may be displayed in conjunction with an image or virtual image of the environment through which a load will be lifted.

Referring again to FIG. **3**, collision monitor **310** monitors for collision related hazards in a vicinity of a lifting device to which sensor unit **110** is coupled. In one embodiment, this collision monitoring function relies on position information from one or more other sensor units coupled that are coupled with other lifting devices. In one embodiment, collision monitor generates a geofence (a virtual barrier based upon positional coordinates) that surrounds the lifting device to which it is coupled. This geofence can be generated in several ways. One embodiment comprises establishing a circular geofences at a preset radius from a position of point **133** of sensor unit **110**. This radius may be set when sensor unit **110** is initially coupled with a load line **112**. Another embodiment comprises using a position (e.g., the position of point **133**) that is associated with a position of sensor unit **110** as a radius for drawing a circular geofence around a position (e.g., the position of point **143**) on the body of lifting device **120**. In either case, the geofence may be re-generated by collision monitor **310** at regular intervals or as positions used in the calculation of the geofence changes.

Collision monitor **310** stores the generated geofence for lifting device **120** and then generates or utilizes similar geofences for other lifting devices in the area to which other sensor units **110** are coupled. Collision monitor **310** then monitors the geofences for occurrence of collision related hazard such as intersection of the geofences or encroachment of the position of a sensor unit or body of one lifting device across the border of a geofence associated with a different lifting device. In one embodiment, wireless transceiver **215** provides geofence information generated or stored in collision monitor **310** to a display unit **113**.

FIG. **5** illustrates a display of example lifting device geofence information **500** that has been generated by one or more lifting device sensor units **110**, according to an embodiment. A geofence **510** is illustrated for lifting device **120**. A second geofence **520** is illustrated for a second lifting device. Collision monitor **310** has generated geofence **510** as a circle about the position of point **143**, with a radius established by the position of point **133** (see FIG. **1**A). Geofence **520** has been generated in a similar manner as a circle about the position of point **521** (located on the body of a second lifting device), with a radius established by the position of point **522** (located on a sensor unit coupled with the load line of the second lifting device). This technique for generating geofences is acceptable for certain lifting devices such as boom cranes, when a sensor unit will be located substantially on a gravity vector beneath a boom tip. Other techniques, to include the use of buffer zones can utilized in other situations.

In one embodiment, collision monitor **310** monitors for a collision hazard such as an intersection **540** of geofences **510** and **520** or an incursion or anticipated incursion (based on direction and speed) of a known position, such as the position of point **133** with a point **541**, **542** on the circumference of geofence **520** or the similar incursion of the position of point **522** with a point **541**, **542** on the circumference of geofence **510**. In one embodiment, when a collision hazard has been monitored by collision monitor **310**, information regarding the occurrence of the collision hazard is provided to avoidance action initiator **315**.

An avoidance action initiator **315** initiates at least one hazard avoidance action in response to a monitored occurrence of a collision related hazard. In various embodiments, among other actions, this can comprise initiating one or more actions such as causing a warning to sound from sound emitting device **251**, causing illumination of an indicator of light emitting device **252**, and/or causing a collision warning to be transmitted to a display unit **113**. It is appreciated that avoidance action initiator **315** may initiate one or more similar actions in response to a monitored occurrence of a load hazard condition being indicated by load monitor **314**. In various embodiments, among other actions, this can comprise one or more of causing a warning to sound from sound emitting device **251**, causing illumination of an indicator of light emitting device **252**, and/or causing a load hazard warning to be transmitted to a display unit **113**. In one embodiment, avoidance action initiator **315** may generate commands which automatically initiate suspension of movement of load **104** to prevent a collision with another object. When it is determined that load **104** can again be moved safely, a safety code can be entered (e.g., using display unit **113**A or **113**B).

Position control **320** generates positioning commands, such as motor control signals for controlling the operation of load line positioner **261** or components thereof.

Power source charger **325** generating a charge for charging power source(s) **217**. In various embodiments power source charger **325** comprises one or more of a solar panel and/or a motion induced power generator (operating in a similar fashion to the rotor of a self-winding watch). It is appreciated that even a small amount of power generated by power source charger **325** will extend the operational duration of power source(s) **217** and thus reduce down time of sensor unit **110**.

In some embodiments, sensor unit(s) **110** and/or other portions of sensor system **100** act as reporting sources, which report information to an asset management system. Such an asset management system may be centralized or decentralized and may be located on or off of a construction site at which one or more reporting sources are located. The reporting sources report information regarding construction equipment assets to which they are coupled. Such information may include position information, operational information, and/or time of operation information. Such an asset management system may comprise a computer system (e.g., computer system **1000**) such as a server computer and/or a database which are used for generating reports, warnings, and the like to be based upon reported information which may include one or more of (but is not limited to) location of operation of a construction equipment asset, time of day of operation of a construction equipment asset, interaction of a construction equipment asset with respect to one or more another construction equipment assets, interaction of a construction equipment asset with respect to a geofence, and/or compliance or non-compliance with a rule or condition of use associated with a construction equipment asset. Typically such a computer system and/or database will be located remotely from a sensor unit **110** and a sensor system **100**.

In some embodiments, sensor unit(s) **110** and/or other portions of sensor system **100** act as reporting sources for reporting information to a lifting device load monitoring system, lifting device collision avoidance system, lifting device load hazard avoidance system, and/or a virtual reality system. Such a load monitoring system, collision avoidance system, load hazard avoidance system, and/or a virtual reality system may be centralized or decentralized and may be located on or off of a construction site at which one or more reporting sources are located. Such a load monitoring system, collision avoidance system, load hazard avoidance system, and/or a virtual reality system may comprise or be implemented with a computer system (e.g., computer system **1000**) or some variation thereof. Typically, such a computer system will be located remotely from a sensor unit **110** and a sensor system **100**. In some embodiments, one or more of object identification, lift plan generation, collision avoidance monitoring, load hazard monitoring, geofence generation, avoidance action initiation, and/or other functions described above with respect to sensor system **100** and/or sensor unit **110** may be handled by a collision avoidance and/or virtual reality system. Such functions may be implemented based in whole or in part on information reported by one or more sensor systems **100** or sensor units **110**.

Example Methods Of Use

With reference to FIGS. **6**, **7**, and **8**, flow diagrams **600**, **700**, and **800** illustrate example procedures used by various embodiments. Flow diagrams **600**, **700**, and **800** include processes and operations that, in various embodiments, are carried out by one or more processors (e.g., processor(s) **1006** of FIG. **10**) under the control of computer-readable and computer-executable instructions. The computer-readable and computer-executable instructions reside, for example, in tangible data storage features such as volatile memory, non-volatile memory, and/or a data storage unit (see e.g., **1008**, **1010**, and **1012** of FIG. **10**). The computer-readable and computer-executable instructions can also reside on any tangible computer readable media such as a hard disk drive, floppy disk, magnetic tape, Compact Disc, Digital Versatile Disc, and the like. The computer-readable and computer-executable instructions, which may reside on computer readable media, are used to control or operate in conjunction with, for example, one or more components of sensor unit **110** and/or and or one or more processors **1006**.

Although specific procedures are disclosed in flow diagrams **600**, **700**, and **800** such procedures are examples. That is, embodiments are well suited to performing various other operations or variations of the operations recited in the processes of flow diagrams **600**, **700**, and **800**. Likewise, in some embodiments, the operations in flow diagrams **600**, **700**, and **800** may be performed in an order different than presented, not all of the operations described in one or more of these flow diagrams may be performed, and/or one or more additional operation may be added.

Example Method Of Monitoring A Lifting Device Load

FIG. **6** is a flow diagram **600** of an example method of monitoring a lifting device load, in accordance with an embodiment. Reference will be made to FIGS. **1**A and **2**A to facilitate the explanation of the operations of the method of flow diagram **600**. In one embodiment, the method of flow diagram **600** describes a use of sensor unit **110** and/or sensor system **100**, while coupled with a lifting device, such as lifting device **120**.

At operation **610**, in one embodiment, a three dimensional position is determined for a point of a sensor unit **110** that is coupled with a load line **112** of a lifting device **120**. This position determining is performed by at least a first GNSS receiver **213** that is coupled with a housing **201** of sensor unit **110**. For example, this can comprise GNSS receiver **213**A determining a three dimensional position of point **133** of sensor unit **110**. This can further comprise GNSS receiver **213**A (assuming it is a dual axis GNSS receiver with multiple antennas) or GNSS receiver **213**B further determining an angular orientation of sensor unit **110**.

At operation **620**, in one embodiment, load position and a load orientation of a load **104** are monitored. The monitored load **104** is coupled with the load line **112** of the lifting device **120**. In one embodiment, this monitoring of the load is performed by load monitor **214** in the manner that has previously been described herein.

At operation **630**, in one embodiment, information is wirelessly provided from the sensor unit to a display unit located apart from the sensor unit. The information includes one or more of the load position, the load orientation, and the sensor unit position. The information may also include position, ranging, laser scanner information, bar code information, RFID information, load related hazard information, or image information related to objects monitored in the field of view of load monitor(s) **214**. Wireless transceiver **215** transmits or provides access of this information. This can comprise wirelessly providing the information for display on a hand-holdable unit (e.g., on display unit **113**B) for display in an operator cab of said lifting device (e.g., on display unit **113**A) or for transmission to another sensor unit **110** or other device or system.

Example Method Of Lifting Device Collision Avoidance

FIG. **7** is a flow diagram **700** of an example method of lifting device collision avoidance, in accordance with an embodiment. Reference will be made to FIGS. **1**A, **2**A, **3**, and **5** to facilitate the explanation of the operations of the method of flow diagram **700**. In one embodiment, the method of flow diagram **700** describes a use of sensor unit **110** (referred to as a lifting device collision avoidance unit) and/or sensor system **100**, while coupled with a lifting device, such as lifting device **120**.

At operation **710**, in one embodiment, a three dimensional position is determined for a point of a collision avoidance sensor unit **110** that is coupled with a load line **112** of a lifting device **120**. This position determining is performed by at least a first GNSS receiver **213** that is coupled with a housing **201** of collision avoidance sensor unit **110**. For example, this can comprise GNSS receiver **213**A determining a three dimensional position of point **133** of collision avoidance sensor unit **110**. This can further comprise GNSS receiver **213**A (assuming it is a dual axis GNSS receiver with multiple antennas) or

GNSS receiver **213**B further determining an angular orientation of collision avoidance sensor unit **110**.

At operation **720**, in one embodiment, a geofence is generated for the first lifting device **120**. The geofence is generated based at least in part on the collision avoidance sensor unit position that has been determined In one embodiment, the geofence is generated by collision monitor **310** in the manner that has been previously described herein.

At operation **730**, in one embodiment, a collision related hazard is monitored for occurrence. Occurrence of a collision related hazard is indicated by encroachment between the first geofence and a second geofence that is associated with a second lifting device. In one embodiment, collision monitor **310** monitors for occurrence of a collision related hazard in the manner previously described herein. The second geofence may be generated by collision monitor **310** based on position information accessed from a second collision avoidance sensor unit that is coupled with the second lifting device, or the second geofence may be received from the second collision avoidance sensor unit.

At operation **740**, in one embodiment, at least one collision hazard avoidance action is initiated in response to a monitored occurrence of a collision related hazard. In one embodiment, this comprises avoidance action initiator **315** initiating an avoidance action in response to collision monitor **310** monitoring an occurrence of collision related hazard. As previously described this can comprise avoidance action initiator **315** causing wireless transceiver **215** to wirelessly provide a collision alert for display on a display unit **113** that is located apart from collision avoidance sensor unit **110**; causing a warning such as a siren, tone, or horn to sound; and/or or causing an indicator such as a light or strobe to illuminate.

At operation **750**, in one embodiment, method of flow diagram **700** additionally comprises wirelessly providing the first geofence and the second geofence from the collision avoidance sensor unit **110** to a display unit **113** located apart from the collision avoidance sensor unit **110**. FIG. **5** shows an example of such information displayed on display unit **113**. It is appreciated that more that two geofences may be provided for display in other embodiments. It is also appreciated that the geofences may be displayed in conjunction with images or virtual images of the working area in and surrounding the geofences.

Example Method Of Lifting Device Load Hazard Avoidance

FIG. **8** is a flow diagram **800** of an example method of lifting device load hazard avoidance, in accordance with an embodiment. Reference will be made to FIGS. **1**A, **2**A, and **3** to facilitate the explanation of the operations of the method of flow diagram **800**. In one embodiment, the method of flow diagram **800** describes a use of sensor unit **110** (referred to as a lifting device load hazard avoidance unit) and/or sensor system **100**, while coupled with a lifting device, such as lifting device **120**.

At operation **810**, in one embodiment, a three dimensional position is determined for a point of a load hazard avoidance sensor unit **110** that is coupled with a load line **112** of a lifting device **120**. This position determining is performed by at least a first GNSS receiver **213** that is coupled with a housing **201** of load hazard avoidance sensor unit **110**. For example, this can comprise GNSS receiver **213**A determining a three dimensional position of point **133** of load hazard avoidance sensor unit **110**. This can further comprise GNSS receiver **213**A (assuming it is a dual axis GNSS receiver with multiple antennas) or GNSS receiver **213**B further determining an angular orientation of load hazard avoidance sensor unit **110**.

At operation **820**, in one embodiment, a load related hazard in a vicinity of a load **104** is monitored for. The load **104** is coupled with load line **112** of lifting device **120**. In one embodiment, the monitoring performed by load monitor(s) **214** in one or more of the manners previously described herein. This includes monitoring for an imminent or potential collision between load **104** and an object in the vicinity of load **104**. This also includes monitoring for loss of visibility of a person **117** beneath load **104**.

At operation **830**, in one embodiment, at least one load related hazard avoidance action is initiated in response to a monitored occurrence of a load related hazard. In one embodiment, this comprises avoidance action initiator **315** initiating an avoidance action in response to load monitor(s) **114** monitoring an occurrence of load related hazard. As previously described this can comprise avoidance action initiator **315** causing wireless transceiver **215** to wirelessly provide a load hazard alert for display on a display unit **113** that is located apart from collision avoidance sensor unit **110**; causing a warning such as a siren, tone, or horn to sound; and/or or causing an indicator such as a light or strobe to illuminate.

Example GNSS Receiver

FIG. **9**, shows an example GNSS receiver **900**, according to one embodiment which may be utilized all or in part one or more of GNSS receivers **213**A, **213**B, **107**, and/or **108**. It is appreciated that different types or variations of GNSS receivers may also be suitable for use in the embodiments described herein. In FIG. **9**, received L**1** and L**2** signals are generated by at least one GPS satellite. Each GPS satellite generates different signal L**1** and L**2** signals and they are processed by different digital channel processors **952** which operate in the same way as one another. FIG. **9** shows GPS signals (L**1**=1575.42 MHz, L**2**=1227.60 MHz) entering GPS receiver **900** through a dual frequency antenna **932**. Antenna **932** may be a magnetically mountable model commercially available from Trimble Navigation of Sunnyvale, Calif. Master oscillator **948** provides the reference oscillator which drives all other clocks in the system. Frequency synthesizer **938** takes the output of master oscillator **948** and generates important clock and local oscillator frequencies used throughout the system. For example, in one embodiment frequency synthesizer **938** generates several timing signals such as a 1st (local oscillator) signal LO**1**at 1400 MHz, a 2nd local oscillator signal LO**2** at 175 MHz, an SCLK (sampling clock) signal at 25 MHz, and a MSEC (millisecond) signal used by the system as a measurement of local reference time.

A filter/LNA (Low Noise Amplifier) **934** performs filtering and low noise amplification of both L**1** and L**2** signals. The noise figure of GPS receiver **900** is dictated by the performance of the filter/LNA combination. The downconvertor **936** mixes both L**1** and L**2** signals in frequency down to approximately 175 MHz and outputs the analogue L**1** and L**2** signals into an IF (intermediate frequency) processor **950**. IF processor **950** takes the analog L**1** and L**2** signals at approximately 175 MHz and converts them into digitally sampled L**1** and L**2** inphase (L**1** I and L**2** I) and quadrature signals (L**1** Q and L**2** Q) at carrier frequencies 420 KHz for L**1** and at 2.6 MHz for L**2** signals respectively.

At least one digital channel processor **952** inputs the digitally sampled L**1** and L**2** inphase and quadrature signals. All digital channel processors **952** are typically are identical by design and typically operate on identical input samples. Each digital channel processor **952** is designed to digitally track the L**1** and L**2** signals produced by one satellite by tracking code and carrier signals and to from code and carrier phase measurements in conjunction with the microprocessor system **954**. One digital channel processor **952** is capable of tracking one satellite in both L**1** and L**2** channels. Microprocessor system **954** is a general purpose computing device (such as computer system **1000** of FIG. **10**) which facilitates tracking and measurements processes, providing pseudorange and carrier phase measurements for a navigation processor **958**. In one embodiment, microprocessor system **954** provides signals to control the operation of one or more digital channel processors **952**. Navigation processor **958** performs the higher level function of combining measurements in such a way as to produce position, velocity and time information for the differential and surveying functions. Storage **960** is coupled with navigation processor **958** and microprocessor system **954**. It is appreciated that storage **960** may comprise a volatile or non-volatile storage such as a RAM or ROM, or some other computer readable memory device or media. In one rover receiver embodiment, navigation processor **958** performs one or more of the methods of position correction.

In some embodiments, microprocessor **954** and/or navigation processor **958** receive additional inputs for use in refining position information determined by GPS receiver **900**. In some embodiments, for example, corrections information is received and utilized. Such corrections information can include differential GPS corrections, RTK corrections, and wide area augmentation system (WAAS) corrections.

Example Computer System Environment

With reference now to FIG. **10**, all or portions of some embodiments described herein are composed of computer-readable and computer-executable instructions that reside, for example, in computer-usable/computer-readable storage media of a computer system. That is, FIG. **10** illustrates one example of a type of computer (computer system **1000**) that can be used in accordance with or to implement various embodiments which are discussed herein. It is appreciated that computer system **1000** of FIG. **10** is only an example and that embodiments as described herein can operate on or within a number of different computer systems including, but not limited to, general purpose networked computer systems, embedded computer systems, server devices, various intermediate devices/nodes, stand alone computer systems, handheld computer systems, multi-media devices, and the like. Computer system **1000** of FIG. **10** is well adapted to having peripheral computer-readable storage media **1002** such as, for example, a floppy disk, a compact disc, digital versatile disc, universal serial bus "thumb" drive, removable memory card, and the like coupled thereto.

System **1000** of FIG. **10** includes an address/data bus **1004** for communicating information, and a processor **1006**A coupled to bus **1004** for processing information and instructions. As depicted in FIG. **10**, system **1000** is also well suited to a multi-processor environment in which a plurality of processors **1006**A, **1006**B, and **1006**C are present. Conversely, system **1000** is also well suited to having a single processor such as, for example, processor **1006**A. Processors **1006**A, **1006**B, and **1006**C may be any of various types of microprocessors. System **1000** also includes data storage features such as a computer usable volatile memory **1008**, e.g., random access memory (RAM), coupled to bus **1004** for storing information and instructions for processors **1006**A, **1006**B, and **1006**C. System **1000** also includes computer usable non-volatile memory **1010**, e.g., read only memory (ROM), coupled to bus **1004** for storing static information and instructions for processors **1006**A, **1006**B, and **1006**C. Also present in system **1000** is a data storage unit **1012** (e.g., a magnetic or optical disk and disk drive) coupled to bus **1004** for storing information and instructions. System **1000** also includes an optional alphanumeric input device **1014** including alphanumeric and function keys coupled to bus **1004** for communicating information and command selections to processor **1006**A or processors **1006**A, **1006**B, and **1006**C. System **1000** also includes an optional cursor control device **1016** coupled to bus **1004** for communicating user input information and command selections to processor **1006**A or processors **1006**A, **1006**B, and **1006**C. In one embodiment, system **1000** also includes an optional display device **1018** coupled to bus **1004** for displaying information.

Referring still to FIG. **10**, optional display device **1018** of FIG. **10** may be a liquid crystal device, cathode ray tube, plasma display device or other display device suitable for creating graphic images and alphanumeric characters recognizable to a user. Optional cursor control device **1016** allows the computer user to dynamically signal the movement of a visible symbol (cursor) on a display screen of display device **1018** and indicate user selections of selectable items displayed on display device **1018**. Many implementations of cursor control device **1016** are known in the art including a trackball, mouse, touch pad, joystick or special keys on alphanumeric input device **1014** capable of signaling movement of a given direction or manner of displacement. Alternatively, it will be appreciated that a cursor can be directed and/or activated via input from alphanumeric input device **1014** using special keys and key sequence commands. System **1000** is also well suited to having a cursor directed by other means such as, for example, voice commands. System **1000** also includes an I/O device **1020** for coupling system **1000** with external entities. For example, in one embodiment, I/O device **1020** is a modem for enabling wired or wireless communications between system **1000** and an external network such as, but not limited to, the Internet.

Referring still to FIG. **10**, various other components are depicted for system **1000**. Specifically, when present, an operating system **1022**, applications **1024**, modules **1026**, and data **1028** are shown as typically residing in one or some combination of computer usable volatile memory **1008** (e.g., RAM), computer usable non-volatile memory **1010** (e.g., ROM), and data storage unit **1012**. In some embodiments, all or portions of various embodiments described herein are stored, for example, as an application **1024** and/or module **1026** in memory locations within RAM **1008**, computer-readable storage media within data storage unit **1012**, peripheral computer-readable storage media **1002**, and/or other tangible computer readable storage media.

Ad-Hoc Wireless Communication Network

FIG. **11** is a block diagram of an example ad-hoc wireless personal area network **1100** in accordance with one or more embodiments. In FIG. **11**, a hook block sensor assembly **1101** is communicatively coupled with display unit **113** via wireless connection **1111**. As described above, in one embodiment, sensor unit **110** may be built into or housed in lifting hook **111**, or a similar load attachment point/mechanism, located on a distal end/portion of load line **112**. For the purpose of brevity, a comprehensive illustration of components of sensor unit **110** which are implemented as hook block sensor assembly are not shown in FIGS. **11** and **12**. However, it is understood that various features and components of sensor unit **110** as described above are combined in implementations of hook block sensor assembly **1101**. In FIG. **11**, hook block sensor assembly **1101** comprises a GNSS antenna **1102** and one or more GNSS receivers **1103**. Hook block sensor assembly **1101** further comprises a power supply **1104** for supplying power to hook block sensor assembly **1101**. It is noted that power supply **1104** can comprise batteries and/or a connection to vehicle supplied power.

A radio transceiver **1105** and wireless antenna **1106** provide wireless communication between hook block sensor assembly **1101** and display unit **113** as indicated by **1111**. Hook block sensor assembly **1101** further comprises one or more sensor units **1107** which are implemented to accomplish load monitoring and/or as described above with reference to load monitors **214**. Sensor units **1107** can further be used for lift plan implementation, position control, collision monitoring, and initiating avoidance actions as discussed above with reference to sensor unit components **216** of FIG. **2**A. These components of hook block sensor assembly **1101** are communicatively and/or electrically coupled with one another as required for performing functions of load monitoring, collision avoidance, and/or load hazard avoidance as described above.

In accordance with various embodiments, the components of hook block sensor assembly **1101** are housed within a housing **201** (see e.g., FIG. **2**D). In one embodiment, housing **201** is coupled with hook **111** (see e.g., FIG. **2**D) and one or more of the components of hook block sensor assembly **1101** described above in FIGS. **2**A, **2**B, and **3** are coupled with housing **201**. Alternatively, the components of hook block sensor assembly **1101** may be coupled with hook **111** and enclosed by housing **201**. It is further noted that other components of sensor unit **110** (e.g., sound emitting device **251**, light emitting device **252**, access hatch **253**, recharge contacts **254**, and/or protective bumper **255**) may be included in housing **201** in accordance with various embodiments.

As discussed above, display unit **113** may be a dedicated display with a wireless transceiver or may be part of an electronic device such as smart phone, netbook, notebook computer, tablet computer, or the like. In the embodiment of FIG. **11**, display unit **113** is removeably coupled with a docking station **1108** which provides connection to a power source (not shown) and a communication connection with L**1** GNSS antenna **1110**. In accordance with various embodiments, display device **1160** may be a liquid crystal device, cathode ray tube, or a touch screen assembly configured to detect the touch or proximity of a user's finger, or other input device, at or near the surface of display device **1160** and to communicate such an event to a processor (e.g., processors **1006**A, **1006**B, and/or **1006**C of FIG. **10**). Display unit **113** further comprises batteries **1161** for providing power to display unit **113** when it is de-coupled from docking station **1108**.

Display unit **113** further comprises one or more wireless radio transceivers **1162** and wireless antenna **1163** for wirelessly communicating with other components of ad-hoc wireless personal area network **1100**. In the embodiment of FIG. **11**, display unit **113** comprises a GNSS receiver **1164** and GNSS antenna **1165** configured for receiving satellite navigation signals and for determining the position of display unit **113**. As shown in FIG. **11**, display unit **113** is communicatively coupled with L**1** GNSS antenna **1110** which is used to receive satellite navigation signals when display unit **113** is coupled with docking station **1108**. This to improve the reception of satellite navigation signals which may be blocked or degraded when display unit **113** is located within cab **121**. An example of a commercially available model of display unit **113** is the Yuma® computer from Trimble Navigation of Sunnyvale, Calif.

In accordance with various embodiments, one or more of wireless radio transceivers **1105** and **1162** may operate on any suitable wireless communication protocol including, but not limited to: WiFi, WiMAX, WWAN, implementations of the IEEE 802.11 specification, cellular, two-way radio, satellite-based cellular (e.g., via the Inmarsat or Iridium communication networks), mesh networking, implementations of the IEEE 802.15.4 specification for personal area networks, and implementations of the Bluetooth® standard. Personal area networks refer to short-range, and often low-data-rate, wireless communications networks. In accordance with embodiments of the present technology, components of ad-hoc wireless personal area network **1100** are configured for automatic detection of other components and for automatically establishing wireless communications. In one embodiment, display unit **113** comprises a first wireless radio transceiver **1162** for communicating with other components of ad-hoc wireless personal area network **1100** and one or more wireless radio transceivers **1162** for wirelessly communicating outside of ad-hoc wireless personal area network **1100**.

FIG. **12** is a block diagram of an example ad-hoc wireless personal area network **1100** in accordance with one or more embodiments. In FIG. **12**, ad-hoc wireless personal area network **1100** comprises hook block sensor assembly **1101** and display unit **113** as described above with reference to FIG. **11**. In FIG. **12**, ad-hoc wireless personal area network **1100** further comprises GNSS antenna unit **1120**. In the embodiment of FIG. **12**, GNSS antenna unit **1120** comprises a GNSS antenna **1121** and GNSS receiver **1122** for receiving satellite navigation signals and for determining the position of GNSS antenna unit **1120**. GNSS antenna unit **1120** further comprises one or more wireless radio transceivers **1123** and wireless antenna **1124** for providing wireless communication with display unit **113** as indicated by **1112**. In accordance with various embodiments, wireless radio transceiver **1123** may operate on any suitable wireless communication protocol including, but not limited to: WiFi, WiMAX, WWAN, implementations of the IEEE 802.11 specification, cellular, two-way radio, satellite-based cellular (e.g., via the Inmarsat or Iridium communication networks), mesh networking, implementations of the IEEE 802.15.4 specification for personal area networks, and implementations of the Bluetooth® standard. An example of a commercially available model of GNSS antenna unit is the SPS 882 Smart GPS Antenna from Trimble Navigation of Sunnyvale, Calif. In one embodiment, GNSS antenna unit **1120** is mounted at the rear of lifting device **120** as shown by global navigation satellite receiver **108** of FIG. **1**A.

In operation, hook block sensor assembly **1101**, display unit **113**, and GNSS antenna unit **1120** are configured to implement an ad-hoc wireless personal area network to assist in or accomplish one or more of efficient load delivery, load monitoring, collision avoidance, and load hazard avoidance as described above. In one embodiment, hook block sensor assembly **1101**, display unit **113**, and GNSS antenna unit **1120** are configured to initiate an automatic discovery process in which components of ad-hoc wireless personal area network **1100** detect each other by exchanging messages without the necessity of user initiation and/or intervention. Additionally, in one embodiment hook block sensor assembly **1101**, display unit **113**, and GNSS antenna unit **1120** are configured to automatically initiate processes to assist in or accomplish one or more of efficient load delivery, load monitoring, collision avoidance, and load hazard avoidance such as determining the position of hook block sensor assembly **1101**, display unit **113**, and/or load **104**. Furthermore, in one embodiment display unit **113** is configured to send and receive data outside of ad-hoc wireless personal are network **1100**. Thus, display unit can be used to receive updates, correction data for position determination, and other instructions for implementing a plan at a site. Additionally, display unit **113** can be used for storing, forwarding, and reporting data used in site monitoring or other purposes.

FIG. **13** is a block diagram of an example communication network **1300** in accordance with one or more embodiments. In FIG. **13**, one or more ad-hoc wireless personal area networks **1100** are communicatively coupled with local area wireless repeater **1302**, cellular/wireless repeater **1303**, and local reference station **1304** via wireless connections **1312** and **1313** respectively. As described above, display unit **113** can include wireless radio transceivers (e.g., **1162** of FIG. **11**) which are configured for communication outside of ad-hoc wireless personal area network **1100**. As an example, implementations of the IEEE 802.11 standards can be used to implement communications between ad-hoc wireless personal area networks **1100**, local area wireless repeater **1302**, cellular/wireless repeater **1303**, and local reference station **1304**. In one embodiment, local area network **1301** utilizes a network protocol that implements an IP address based communication scheme to implement communications between various elements. In FIG. **13**, local area wireless repeater **1302**, cellular wireless repeater **1303**, and local reference station **1304** are shown as separate components which represent a fixed infrastructure for implementing local area network **1301**. However, in accordance with embodiments some of the functions separately shown in local area network **1301** can be combined in a single device. In one embodiment, a display unit **113** that includes one or more of the different types of ad-hoc wireless personal area networks **1100** can be configured to store and forward messages to/from other of the ad-hoc wireless personal area networks **1100** comprising local area network **1301**. Alternatively, local area wireless repeater **1302** may be mounted in another vehicle at a site at which local area network **1301** is located.

In one embodiment, communication between Internet **1310** and local area network **1301** is accomplished via cellular/wireless repeater **1303**. In one embodiment, cellular/wireless repeater **1303** comprises a cellular telephone transceiver for communicating with Internet **1310** via cellular network **1350** using wireless connection **1351**. Cellular/wireless repeater **1303** further comprises a wireless transceiver for communication with other components of local area network **1301**. An example of a commercially available model of cellular/wireless repeater **1303** is the Nomad® handheld computer from Trimble Navigation of Sunnyvale, Calif. In one embodiment, communication between Internet **1310** and local area network **1301** is accomplished via wireless transceiver **1305** which is communicatively coupled with Internet **1310**. Wireless transceiver **1305** is in turn communicatively coupled with local area wireless repeater **1302** using wireless connection **1331**. It is noted that in accordance with one embodiment, a connection to Internet **1310** may be available at the site at which local area network **1301** is located and that wireless transceiver **1305** may fulfill the function of local area wireless repeater **1302** in that instance. In accordance with another embodiment, a connection to Internet **1310** can be made directly from display unit **113**. In operation, display unit **113** can initiate wireless communication with Internet **1310** either directly using wireless radio transceiver **1162**, or via local area wireless repeater **1302** and/or cellular/wireless repeater **1303**. In one embodiment, establishing communications with Internet **1310** is accomplished in a manner that is transparent to a user of display unit **113**. In other words, display unit **113** can be configured to automatically exchange messages with local area wireless repeater **1302**, cellular/wireless repeater **1303**, or a website of Internet **1310** without the necessity of user initiation or intervention. These messages can be used for receiving updates, position reporting of load **104**, or lifting device **120**. The data in these messages can be used for purposes including, but not limited to, collision monitoring, traffic control at a site, hazard avoidance, site monitoring, status and position monitoring of equipment, vehicle logging, etc.

In accordance with embodiments, Internet **1310** is coupled with a geographically independent corrections system **1315** and with a geographically dependent correction system **1320**. In accordance with various embodiments, it is desired to deliver reference data to GNSS receivers to improve the precision of determining a position. This reference data allows compensating for error sources known to degrade the precision of determining a position such as satellite and receiver clock errors, signal propagation delays, and satellite orbit error. In one embodiment, geographically independent corrections system **1315** determines the correct position of GNSS satellites in space as well as clock errors associated with each of the GNSS satellites and distributes an error message **1316** to facilitate a GNSS receiver to refine determining its position with a precision of ten centimeters or less. In accordance with various embodiments, error message **1316** can be distributed via Internet **1310**. In one embodiment, error message **1316** is sent from Internet **1310** to communication satellites **1340** via uplink **1341**. Communication satellites **1340** then convey error message **1316** to local area network **1301** via wireless connection **1342**. In one embodiment, GNSS receiver **1164** of display unit **113** determines which GNSS satellites are in its field of view and uses the orbit and clock error data pertaining to these satellites from error message **1316** to refine determining its position. Alternatively, error message **1316** can be conveyed from communication satellites **1340** to local area wireless repeater **1302** or cellular/wireless repeater **1303**. In another embodiment, error message **1316** is sent via cellular network **1350** to cellular/wireless repeater **1303** and then distributed throughout local area network **1301**.

Geographically dependent corrections system **1320** uses a network of reference stations to determine error sources which are more applicable to a particular to the region due to local weather and/or local atmospheric conditions due to ionospheric and/or tropospheric propagation delays. In accordance with one embodiment, a subset of the network of reference stations can be selected in order to generate reference data descriptive of these error sources. This reference data can be used by GNSS receiver **1164** to refine determining its position with a precision of approximately one centimeter or less. Again, the reference data descriptive of these error sources can be distributed via Internet **1310** to communication satellites **1340**, or to cellular network **1350** for distribution to local area network via cellular/wireless repeater **1303** for example. One implementation of geographically dependent correction system **1320** is described in U.S. patent application Ser. No. 12/241,451, titled "Method and System for Location-Dependent Time-Specific Correction Data," by James M. Janky, Ulrich Vollath, and Nicholas Talbot, assigned to the assignee of the present invention and incorporated by reference in its entirety herein.

FIG. **14** is a flowchart of a method **1400** for communicatively coupling a sensor unit system in accordance with one or more embodiments. In operation **1410** of FIG. **14**, data is received from a first global navigation satellite system (GNSS) receiver of a display unit, wherein the first GNSS receiver is configured for determining a position of the display unit in three dimensions. As described above, in accordance with various embodiments display unit **113** comprises GNSS receiver **1164** which is configured to determine the position of display unit **113** in three dimensions based upon GNSS signals received via GNSS antenna **1165**. Furthermore, in accordance with various embodiments display unit **113** further comprises one or more wireless radio transceivers **1165**. In accordance with various embodiments, at least one of the wireless radio transceivers **1165** is configured for communicating via a wireless personal area network connection (e.g., **111** of FIG. **11**).

In operation **1420** of FIG. **14**, data is received from a second GNSS receiver of a sensor unit via a wireless radio transceiver using a wireless Personal Area Network (PAN) connection, wherein the second GNSS receiver is configured for determining a position of the sensor unit in three dimensions. In accordance with various embodiments display unit **113** receives data from hook block sensor assembly **1101** via wireless connection **1111**. As described above, wireless connection **1111** is a wireless personal area network connection in accordance with embodiments. In accordance with various embodiments hook block sensor assembly **1101** can convey data from one or more GNSS receiver **1103** via wireless connection **1111**. Additionally, hook block sensor assembly **1101** can convey data from one or more of load monitors **214**.

Embodiments of the present technology are thus described. While the present technology has been described in particular embodiments, it should be appreciated that the present technology should not be construed as limited to these embodiments alone, but rather construed according to the following claims.

What is claimed is:

1. A hook block sensor assembly comprising:

a housing configured to removably couple about a lifting hook of a lifting device;

a first global navigation satellite system (GNSS) receiver coupled with said housing and configured for determining a hook block sensor assembly position in three dimensions;

a load monitor coupled with said housing and configured for monitoring a load coupled with said lifting hook, including monitoring a load position and a load orientation of said load; and

a wireless transceiver coupled with said housing and configured for wirelessly providing information including said load position, said load orientation, and said hook block sensor assembly position, to a display unit located apart from said hook block sensor assembly.

2. The hook block sensor assembly of claim **1**, further comprising:

a second GNSS receiver coupled with said housing and configured for determining an angular orientation of said hook block sensor assembly.

3. The hook block sensor assembly of claim **1**, further comprising:

a collision monitor coupled with said housing and configured monitoring for collision related hazards in a vicinity of said lifting hook.

4. The hook block sensor assembly of claim **3**, further comprising:

an avoidance action initiator coupled with said housing configured for initiating at least one hazard avoidance action in response to a monitored occurrence of said collision related hazard.

5. The hook block sensor assembly of claim **1**, further comprising:

a power source coupled with said housing and configured for providing electrical power for operating electrical components of said hook block sensor assembly.

6. The hook block sensor assembly of claim **5**, further comprising:

a power source charger coupled with said housing and configured for generating a charge for charging said power source.

7. The hook block sensor assembly of claim **1**, further comprising:

a protective bumper disposed on a portion of an external surface of said housing.

8. The hook block sensor assembly of claim **1**, further comprising:

a lift plan generator coupled with said housing and configured for generating a lift plan for lifting said load to a destination associated with said load.

9. The hook block sensor assembly of claim **1**, wherein said load monitor is selected from the group of a camera, a plurality of cameras, an ultrasonic sensor, a laser scanner, a bar code scanner, a radio frequency identification device transceiver, and an inertial sensor.

10. The hook block sensor assembly of claim **1**, wherein said load monitor is further configured for monitoring for load related hazards in a vicinity of said load.

11. The hook block sensor assembly of claim **1**, wherein said load monitor is configured for monitoring for one or more object identifiers coupled with said load or one or more other objects in a field of view of said load monitor from said hook block sensor assembly.

12. The hook block sensor assembly of claim **1**, wherein said transceiver is further configured for wirelessly communicating with a second sensor unit coupled with a second lifting device.

13. The hook block sensor assembly of claim **1**, wherein said transceiver is further configured for accessing load cell information of said lifting device, said load cell information indicative of said lifting device taking or releasing said load with said lifting hook.

14. The hook block sensor assembly of claim **1**, wherein said housing includes a power source access hatch for accessing a power source of said hook block sensor assembly while said hook block sensor assembly is coupled with said lifting hook.

15. The hook block sensor assembly of claim **14**, wherein said housing includes recharge contacts, said recharge contacts accessible for recharging said power source of said hook block sensor assembly while said hook block sensor assembly is coupled with said lifting hook.

16. The hook block sensor assembly of claim **1**, wherein at least a portion of said housing is radio frequency transparent to GNSS signals for facilitating receipt of said GNSS signals by said first GNSS receiver.

17. The hook block sensor assembly of claim **1**, wherein said housing comprises at least two portions configured for removably coupling with one another about said lifting hook.

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